PB81-128522

Cost Comparisons of Treatment and Disposal Alternatives for Hazardous Wastes Volume II. Appendices

SCS Engineers, Inc.
Redmond, WA

Prepared for

Municipal Environmental Research Lab.
Cincinnati, OH

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PB81-128522

EPA-600/2-80-208
December 1980

COST COMPARISONS OF TREATMENT AND DISPOSAL ALTERNATIVES FOR HAZARDOUS WASTES

Volume II. Appendices

by

Warren G. Hansen and Howard L. Rishel
SCS Engineers
Redmond, Washington 98052

Contract No. 68-03-2754

Project Officer

Oscar W. Albrecht
Solid and Hazardous Waste Research Division
Municipal Environmental Research Laboratory
Cincinnati, Ohio 45268

MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

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SPRINGFIELD, VA 22161

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/ 2-80-208	2.
3. RECIPIENT'S ACCESSION NO. PB81 128522	
4. TITLE AND SUBTITLE Cost Comparisons of Treatment and Disposal Alternatives for Hazardous Wastes (Vol II)	5. REPORT DATE December 1980
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Warren G. Hansen & Howard L. Rishel	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS S C S Engineers 2875 152nd Avenue N.E. Redmond, Washington 98052	10. PROGRAM ELEMENT NO. T2.3 (1DC618)
	11. CONTRACT/GRANT NO. Contract NO. 68-03-2754
12. SPONSORING AGENCY NAME AND ADDRESS Municipal Environmental Reseatch Laboratory--Cin., OH. Office of Research and Development U.S. Environmental Protection Agency Cincinnati, Ohio 45268	13. TYPE OF REPORT AND PERIOD COVERED Final
	14. SPONSORING AGENCY CODE EPA/600/14

15. SUPPLEMENTARY NOTES

Project Officer: Oscar W. Albrecht SHWRD, CINCINNATI, Ohio 45268 (513) 684-4216

16. ABSTRACT

Treatment and disposal alternatives and costs for hazardous wastes from the organic chemicals, inorganic chemicals, and electroplating and metal finishing industries are evaluated. The 16 treatment and 5 disposal technologies were based on applicability to the industry categories, availability of cost and performance data, and effectiveness in reducing or eliminating hazardous waste constituents. Costs were aggregated at the technology level and entered in computer-linked models at the unit cost or component level. Volume II contains applicable portions of the Resource Conservation and Recovery Act, capital unit cost and operation/maintenance cost data files, curve fitting for cost files, module descriptions, and system variable equations. Volume II is intended for those desiring the supporting data for Volume I.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
cost-effectiveness cost estimates hazardous materials waste treatment cost	Organic Chemical Waste Inorganic Chemical Waste Hazardous Waste Costs Electroplating Waste Hazardous Waste	13B 14A

18. DISTRIBUTION STATEMENT General distribution	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

EPA Form 2220-1 (Rev. 4-77)

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FOREWORD

The U.S. Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimonies to the deterioration of our natural environment. The complexity of that environment and the interplay of its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution; it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems to treat and manage wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, to preserve and treat public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research and provides a most vital communications link between the researcher and the user community.

The purpose of this study is to enhance the understanding of hazardous waste treatment and disposal economies. The multitude of applicable and emerging technologies in this area must be described and priced to allow waste managers to make informed decisions. This report provides the user community with the necessary cost data, analytical and comparative techniques, and recommendations for cost-effective management options based on the type of waste and scale of operation.

Francis T. Mayo,
Director
Municipal Environmental Research
Laboratory

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ABSTRACT

This project is intended to standardize, update, and evaluate cost and technological data pertaining to treatment/disposal options for hazardous wastes from the organic chemicals, inorganic chemicals, and the electroplating and metal finishing industries. Sixteen treatment and five disposal technologies were selected for study based on their applicability within the industrial categories, the availability of cost and performance data, and their overall effectiveness in reducing or eliminating the hazardous waste constituents.

Each technology was assessed in terms of its unit processes or modules, and computer-linked models were developed for calculating capital and operation/maintenance costs at the unit process level. Costs were then aggregated at the technology level together with all applicable indirect capital and operation/maintenance costs. Cost data were entered in the models at the unit cost or cost component level (e.g., dollars/yd^3 of concrete), and the data files were designed to accommodate economies of scale.

Technology costs derived from the analyses (provided in both tabular and graph format) are presented for site preparation, structures, mechanical equipment, electrical equipment, land and other capital. Operation/maintenance cost categories include three classes of labor, energy, maintenance, and chemicals. Final cost comparisons among treatment/disposal technologies applicable to similar waste streams are made on a life cycle average cost basis.

Risks associated with the existence and operation of each technology are also assessed. Each technology is rated and compared in terms of susceptibility to catastrophic events, unexpected downtime, and adverse environmental impacts.

This report was submitted in fulfillment of Contract No. 68-03-2754 by SCS Engineers under the sponsorship of the U.S. Environmental Protection Agency. It covers the period September 25, 1978, to August 25, 1979, and work was completed as of October 25, 1979.

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LIST OF ABBREVIATIONS AND METRIC CONVERSIONS

Abbreviation	Definition	Metric Equivalent
EA	each	N.A.
SF	square feet	x 0.0929 = square meters
LF	linear feet	x 0.3048 = linear meters
FT	feet	x 0.3048 = meters
DIA"	diameter (in inches)	x 2.54 = centimeters
DIA'	diameter (in feet)	x 0.3048 = meters
HP	horsepower-hour	x = 0.7457 KWH
LBS	pounds	x 0.454 = kilograms
GAL	gallons	x 3.785 = liters
GPM	gallons per minute	x 3.785 = liters per minute
GPD	gallons per day	x 3.785 = liters per day
CF	cubic feet	x 0.028 = cubic meters
BTU	British Thermal Unit	x 1.06×10^{10} = ergs
LBS/HR	pounds per hour	x 0.454 = kilograms per hour
TONS/HR	tons per hour	x 0.907 = metric tons per hour
IN	inch	x 2.54 = centimeter
CY	cubic yard	x 0.765 = cubic meter
BDFT	board feet	x 0.3048 = board meters
KWH	kilowatt-hour	N.A.
^{o}C	degrees centigrade	x 9/5+32 = degrees Fahrenheit
PPM	parts per million (milligrams per liter)	N.A.
PSIG	pounds per square inch	x 703.1 = kilograms per sq. meter
BOD	biological oxygen demand	N.A.
TSS	total suspended solids	N.A.

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APPENDIX A

RESOURCE CONSERVATION RECOVERY ACT SECTION 250.45*

§ 250.45 Standards for treatment/disposal.

(a) Where practical, disposal of hazardous waste shall be avoided and alternatives such as destruction, treatment to render the waste non-hazardous, or treatment for purposes of resource recovery and reuse shall be employed.

(b) All facilities which dispose of discrete radioactive wastes shall be licensed by the U.S. Nuclear Regulatory Commission, or an Agreement State.

(c) An owner/operator of a facility shall not treat or dispose of hazardous waste in a landfill, surface impoundment, basin, or landfarm if the waste has any one of the following characteristics:

(i) Ignitable waste, as defined in § 250.13(a), Subpart A;

(ii) Reactive waste, as defined in § 250.13(c), Subpart A;

(iii) Contains chemical groups which are incompatible with wastes in the facility with which they may become mixed (see Appendix I); or

(iv) Volatile waste.

NOTE.—A landfill, surface impoundment, basin, or landfarm facility may be used to treat or dispose of ignitable, reactive, volatile, or incompatible waste provided that the owner/operator can demonstrate to the Regional Administrator, at the time a permit is issued pursuant to Subpart E, that such treatment or disposal will not: (1) contribute any airborne contaminant to the atmosphere such that concentrations above the source have the potential: (i) to exceed permissible exposure levels for that airborne contaminant promulgated in 29 CFR 1910.1000 (see Appendix III) pursuant to the Occupational Safety and Health Act of 1970, or (ii) to contribute two or more listed airborne contaminants in a manner which causes the sum of the following expression to exceed unity:

$$E_m = \frac{C_1}{L_1} + \frac{C_2}{L_2} + \cdots \frac{C_n}{L_n}$$

Where:

E_m is the equivalent exposure of a mixture of airborne contaminants, C is the concentration of a particular contaminant, L is the exposure limit for that contaminant (29 CFR 1910.1000, Table Z-1, Z-2, Z-3), and (2) damage the structural integrity of the landfill, surface impoundment, or basin, or affect the attenuation capacity of a landfarm, through heat generation, fires, or explosive reactions.

§ 250.45-1 Incineration.

(a) An owner/operator of an incinerator shall comply with the requirements of this Section when burning hazardous waste.

(b) *Trial burns.* (1) The owner/operator shall conduct a trial burn for each hazardous waste which is significantly different in physical and chemical characteristics from any previously demonstrated under equivalent conditions. The trial burn shall include as a minimum the following determinations:

(i) An analysis of the hazardous waste for concentrations of halogens and principal hazardous components;

(ii) An analysis of the ash residues and scrubber effluent for the principal hazardous components;

(iii) An analysis of the exhaust gas for the concentrations of the principal hazardous components, hydrogen halides, CO, CO_2, O_2, and total particulates;

*Reprinted from the Federal Register; Monday, December 18, 1978, Part IV; Environmental Protection Agency; Hazardous Waste.

(iv) An identification of sources of fugitive emissions and their means of control;

(v) A measurement of combustion temperature and computation of residence time;

(vi) A computation of combustion efficiency and destruction efficiency;

(vii) A computation of scrubber efficiency in removing halogens;

(2) The results from each trial burn shall be submitted to the Regional Administrator.

(c) *Monitoring.* The owner/operator shall monitor and record the following in each trial burn and each operational burn:

(1) Combustion temperature;

(2) Carbon monoxide and oxygen concentrations in the exhaust gas on a continuous basis, and

(3) The rate of hazardous waste, fuel, and excess air fed to the combustion system at regular intervals of no longer than 15 minutes.

(d) *Combustion criteria.* (1) The incinerator shall operate at greater than 1000° C combustion temperature, greater than 2 seconds retention time, and greater than 2 percent excess oxygen during incineration of hazardous waste, unless the waste is hazardous because it contains halogenated aromatic hydrocarbons, in which case the incinerator shall operate at greater than 1200° C combustion temperature, greater than two seconds retention time, and greater than 3 percent excess oxygen during incineration of the hazardous waste.

(2) The incinerator shall be operated at a combustion efficiency equal to or greater than 99.9 percent, as defined in the following equation:

$$CE = \frac{C_{CO_2}}{C_{CO_2} + C_{CO}} \times 100$$

Where:

CE = combustion efficiency
C_{CO_2} = concentration of CO_2 in exhaust gas
C_{CO} = concentration of CO in exhaust gas

Incinerators that burn waste that is hazardous only because it is listed in § 250.14(b)(1) are exempt from this required.

NOTE TO (b) (1) AND (2).—Incinerators may operate at other conditions of temperature, retention time, and combusion efficiency if the facility owner/operator can demonstrate that an equivalent degree of combustion will be provided under alternate combustion criteria to the conditions prescribed above.

(3) The incinerator shall be operated with a functioning device to cut off automatically waste feed to the incinerator when significant changes occur in flame combustion temperature, excess air, or scrubber water pressure.

(e) *Destruction and emission control criteria.* (1) The incinerator shall be designed, constructed, and operated to maintain a destruction efficiency of 99.99 percent as defined in the following equation:

$$DE = \left(\frac{W_{in} - W_{out}}{W_{in}}\right) \times 100$$

Where:

DE = destruction efficiency
W_{in} = mass feed rate of principal toxic components of waste going into the incinerator (g/min)
W_{out} = mass emissions rate of principal toxic components in waste in the incinerator combusion zone (g/min).

Incinerators that burn waste that is hazardous only because it is listed in § 250.14(b)(1) are exempt from this requirement.

(2) An incinerator used to thermally degrade hazardous waste containing more than 0.5 percent halogens shall be equipped with emission control equipment capable of removing 99 percent of the halogens from the exhaust gases.

(3) The incinerator shall be operated in a manner that assures that emissions of particulate matter do not exceed 270 milligrams per dry standard cubic meter (0.12 grains per dry standard cubic foot) at zero excess air. Compliance with this requirement may be achieved by having particulate emissions which, when corrected to 12 percent CO_2 by the formula below, are less than 180 milligrams per standard cubic meter (0.08 grains per dry standard cubic foot).

$$PE_c = PE_m \times \frac{C_s}{C_m \times 1.5}$$

Where:

Pe_c = corrected particulate emissions, mg/m^3 (gr/dscf)
PE_m = measured particulate emissions, mg/m^3 (gr/dscf)
C_s = stoichiometric CO_2 concentration, ppm
C_m = measured CO_2 concentration, ppm

(4) The incinerator shall be designed, constructed, and operated so that fugitive emissions of unburned hazardous waste and combustion products are controlled.

§ 250.45-2 Landfills.

(a) *Site Selection.*

(1) A landfill shall be located, designed, constructed, and operated to prevent direct contact between the landfill and navigable water.

(2) A landfill shall be located, designed, and constructed so that the bottom of its liner system or natural in-place soil barrier is at least 1.5 meters (5 feet) above the historical high water table.

NOTE.—The bottom of any liner system or natural in-place soil barrier may be located less that 1.5 meters (5 feet) above the historical high water table, provided the owner/operator can demonstrate, to the Regional Administrator, at the time a permit is issued pursuant to Subpart E, that no direct contact will occur between the landfill and the water table and a leachate monitoring system as required by § 250.43-8 can be adequately installed and maintained in the lesser space.

(3) A landfill shall be at least 150 meters (500 feet) from any functioning public or private water supply or livestock water supply.

NOTE.—A landfill may be less than 150 meters (500 feet) from any functioning public or private water supply or livestock water supply, provided the owner/operator can demonstrate to the Regional Administrator, at the time a permit is issued pursuant to Subpart E, that:

(i) No direct contact will occur between the landfill and any functioning public or private water supply or livestock water supply;

(ii) No mixing of the landfill leach- ate (including groundwater or surface water contaminated with leachate) with the public or private water supply or livestock water supply will occur; and

(iii) A groundwater monitoring system as required by § 250.43-8 has been installed and is being adequately maintained.

(b) *Construction and operation.* (1) A landfill shall be located, designed, constructed, and operated to minimize erosion, landslides, and slumping.

(2) A landfill shall be located, designed, constructed, and operated so that its liner system or natural in-place soil barrier is compatible with all of the waste to be landfilled.

(3) The exact location of each hazardous waste and the dimensions of each cell with respect to permanently surveyed bench marks shall be recorded. The contents of each cell shall also be recorded. These records shall be handled as specified in § 250.43-5(b).

(4) Waste, containerized or non-containerized, that is incompatible (see Appendix I) shall be disposed of in separate landfill cells.

(5) Each container of liquid hazardous waste shall be surrounded by an amount of sorbent inert material capable of absorbing all of the liquid contents of the container.

(6) The following hazardous waste shall not be disposed in a landfill:

(i) Ignitable waste, as defined in § 250.13(a) of Subpart A;

(ii) Reactive waste, as defined in § 250.13(c) of Subpart A;

(iii) Volatile waste;

NOTE.—See Note in § 250.45(c).

(iv) Bulk liquids, semi-solids, and sludges.

NOTE.—Bulk liquids, semi-solids, and sludges may be disposed of at a landfill provided such waste is pretreated and/or stabilized (e.g., chemically fixed, evaporated, mixed with dry inert absorbant), or treated and/or stabilized in the landfill (e.g., mixed with municipal refuse at acceptable ratios) to reduce its liquid content or increase its solid content so that a non-flowing consistency is achieved to eliminate the presence of free liquids prior to final disposal in a landfill.

(7) Diversion structures (e.g., dikes, drainage ditches) shall be constructed such that surface water runoff will be prevented from entering the landfill.

NOTE.—Diversion structures may not be necessary provided the owner/operator can demonstrate to the Regional Administrator, at the time a permit is issued pursuant to Subpart E, that the landfill facility is located so that the local topography will prevent surface water runoff from entering the facility.

(8) Surface water which has been in contact with the active portions of a landfill shall be collected and treated or disposed of as a hazardous waste in accordance with requirements in this Subpart unless it is analyzed and found not to be hazardous waste as identified or listed in Subpart A or it is collected and discharged into a navigable water in compliance with a NPDES permit issued under the Clean Water Act.

(9) Where gases are generated within the landfill, a gas collection and control system shall be installed to control the vertical and horizontal escape of gases from the landfill.

NOTE.—Gas collection and control systems shall not be required provided the owner/operator can demonstrate to the Regional Administrator, at the time a permit is issued pursuant to Subpart E, that gases will not be generated in the landfill or that gases generated will not be in violation of the air contaminant limits specified in the Note associated with § 250.45(c) and will not create a flammable or explosive atmosphere.

(10) A minimum of 15 centimeters (6 inches) of cover material shall be applied daily on active portions of a landfill. Active portions which will not have additional waste placed on them for at least one week shall be covered with 30 centimeters (12 inches) of cover material.

NOTE.—An owner/operator may use covers of different thicknesses and/or apply them at different frequencies if he can demonstrate to the Regional Administrator, at the time a permit is issued pursuant to Subpart E, that the possibility of fire or explosion or the harboring, feeding, and breeding of land burrowing animals and vectors will be controlled to an equivalent degree.

(11) In areas where evaporation exceeds precipitation by 20 inches or more and where natural geologic conditions allow, a landfill shall have a natural in-place soil barrier on the entire bottom and sides of the landfill. This barrier shall be at least 3 meters (10 feet) in thickness and consist of natural in-place soil which has a permeability of less than or equal to 1×10^{-7} cm/sec. and meets the requirements of § 250.45(b)(14).

NOTE.—A natural in-place soil barrier using natural in-place soils of different thicknesses and permeabilities may be used, provided the barrier has a thickness greater than or equal to 1.5 meters (5 feet), and provided that the owner/operator of the landfill can demonstrate to the Regional Administrator, at the time a permit is issued pursuant to Subpart E, that it will provide equivalent containment of leachate.

(12) An owner/operator of a landfill using the design in paragraph (b)(11) or any similar design which does not have a leachate collection system shall demonstrate to the Regional Administrator, at the time a permit is issued pursuant to Subpart E, that liquids will not accumulate in the landfill to the extent that they may be discharged to the surface or to groundwater.

(13) In areas where climatic and natural geologic conditions do not allow meeting the requirements of paragraph (b)(11), a landfill shall have either one of the following liner systems covering the entire bottom and sides of the landfill:

(i) *Design I.* The liner system shall have a slope of at least 1 percent at all points and be connected at all low points to one or more leachate collection sumps, (which meet the specifications in paragraph (b)(17)), so that leachate formed in the landfill will flow by gravity into the leachate collection sump(s) from which the leachate can be removed and treated or disposed of as specified herein. The liner system shall consist of:

(A) A soil liner which is at least 1.5 meters (5 feet) in thickness and composed of natural in-place soil or emplaced soil which has a permeability less than or equal to 1×10^{-7} cm/sec. and meets the requirements of paragraph (b)(14); and

(B) A leachate collection and removal system overlying the soil liner which is at least 30 centimeters (12 inches) in thickness and composed of permeable soil capable of permitting leachate to move rapidly through the system and into the leachate collection sump(s).

(iii) *Design II.* The liner system shall have a slope of at least 1 percent at all points and be connected at all low points to one or more leachate collection sumps (which meet the specifications of paragraph (b)(17)), so that leachate formed in the landfill will flow by gravity into the leachate collection sump(s) from which the leachate can be removed and treated or disposed of as specified herein. The landfill liner system shall consist of:

(A) A leachate detection and removal system, placed on the natural base of the landfill, which shall consist of a minimum of 15 centimeters (6 inches) of permeable soil capable of permitting leachate to move rapidly through the system and into the leachate collection sumps;

(B) A membrane liner system overlying the leachate detection and removal system composed of a 15 centimeter (6 inch) layer of clean permeable sand or soil overlaid with a synthetic membrane liner which meets the specifications in paragraph (b)(17) and which is overlaid with a 15 centimeter (6 inch) layer of clean permeable sand or soil;

(C) A soil liner overlying the membrane liner system which is at least 1 meter (3 feet) in thickness and composed of soil which has a permeability less than or equal to 1×10^{-7} cm/sec. and meets the requirements of paragraph (b)(14); and

(D) A leachate collection and removal system overlying the soil liner which is at least 30 centimeters (12 inches) in thickness and composed of permeable soil capable of permitting leachate to move rapidly through the system and into the leachate collection sumps.

NOTE.—A landfill may use a different liner system than the two described above provided the owner/operator can demonstrate to the Regional Administrator, at the time a permit is issued pursuant to Subpart E, that

the alternate liner system includes a liner and a leachate collection and removal system that provides equivalent or greater leachate containment, collection, and removal.

(14) The soils used in a soil liner or natural inplace soil barrier shall meet the following minimum criteria:

(i) Be classified under the Unified Soil Classification System CL, CH, SC and OH (ASTM Standard D2487-69),

(ii) Allow greater than 30 percent passage through a no. 200 sieve (ASTM Test D1140),

(iii) Have a liquid limit equal to or greater than 30 units (ASTM Test D423),

(iv) Have plasticity greater than or equal to 15 units (ASTM Test D424),

(v) Have a pH of 7.0 or higher (see Appendix IV), and

(vi) Have a permeability not adversely affected by anticipated waste.

NOTE.—Soil not meeting the above criteria may be used provided the owner/operator can demonstrate to the Regional Administrator, at the time a permit is issued pursuant to Subpart E, that such soil will provide equivalent or greater structural stability and waste containment and attenuation, and will not be adversely affected by the anticipated waste.

(15) A synthetic membrane liner shall meet the following minimum criteria:

(i) Be of adequate strength and thickness to insure mechanical integrity and have a minimum thickness of 20 mils;

(ii) Be compatible with the waste to be landfilled;

(iii) Be resistant to attack from soil bacteria and fungus;

(iv) Have ample weather resistance to withstand the stress of extreme heat, freezing, and thawing;

(v) Have adequate tensile strength to elongate sufficiently and withstand the stress of installation and/or use of machinery and equipment;

(vi) Be of uniform thickness, free from thin spots, cracks, tears, blisters, and foreign particles;

(vii) Be placed on a stable base; and

(viii) Have a permeability less than or equal to 1×10^{-12} cm/sec or its equivalent.

(16) A landfill overlying an underground drinking water source shall have a groundwater monitoring system and a leachate monitoring system as specified in § 250.43-8.

(17) A leachate collection sump (as required in the liner systems specified in paragraph (b)(13)) shall be designed and constructed:

(i) Of materials both compatible with and impermeable to the leachate formed in the landfill;

(ii) So that the sump is accessible for removal of leachate if the sump pump becomes inoperative and/or the stand pipe for removal of leachate becomes damaged; and

(iii) With a volume equal to or greater than three-months expected volume of leachate but no less than 1,000 gallons.

(18) The owner/operator shall remove leachate from a leachate collection sump as frequently as necessary to maintain gravity flow in the leachate collection and removal system and shall check the leachate collection sump at least monthly to assure compliance with this requirement.

(19) Landfill liner systems and natural in-place soil barriers shall not be placed over earth materials exhibiting a permeability of greater than 1×10^{-4} cm/sec.

(c) *Closure.* (1) At closure, the owner/operator of a landfill shall place a final cover over the landfill. This final cover shall consist of at least 15 centimeters (6 inches) of soil with a permeability less than or equal to 1×10^{-7} cm/sec which meets the criteria of § 250.45-2(b)(14), underlying 45 centimeters (18 inches) of soil capable of supporting indigenous vegetation. The top 15 centimeters (6 inches) of this cover shall be topsoil.

NOTE.—A final cover using different thicknesses and permeabilities may be used provided the owner/operator can demonstrate to the Regional Administrator that it will provide equivalent control of infiltration of water, equivalent control of sublimation or evaporation of harmful pollutants into the air, and equivalent erosion control. The owner/operator must also demonstrate that the final cover will support indigenous vegetation.

(2) Where trees or other deep-rooted vegetation are to be planted on the completed landfill, the final cover shall consist of the 15 centimeter (6 inch) soil layer specified in paragraph (c)(1) underlying at least 1 meter (3 feet) of soil capable of supporting the deep-rooted vegetation and indigenous vegetation.

NOTE.—The upper layer soil thickness for deep-rooted vegetation may be less than 1 meter (3 feet) provided the owner/operator can demonstrate to the Regional Administrator that the roots of the vegetation will not penetrate the 6-inch clay cover.

(3) The final grade of the final cover shall not exceed 33 percent. Where final grades exceed 10 percent, horizontal terraces shall be constructed. Terraces shall be of sufficient width and height to withstand a 24-hour, 25-year storm. A terrace shall be placed at every 10 feet of rise in elevation when the slope is less than 20 percent

and at every 20 feet or rise in elevation when the slope is greater than 20 percent.

NOTE.—The final grade may be of different design and slope provided the owner/operator can demonstrate to the Regional Administrator that water will not pool on the final cover and that erosion will be minimized.

(d) *Post-closure care.* (1) During the post-closure period, which shall continue at the landfill for a period of at least 20 years (see § 250.43-7), the owner-operator of the landfill:

(i) Shall maintain the soil integrity, slope, and vegetative cover of the final cover and all diversion and drainage structures;

(ii) Shall maintain the groundwater and leachate monitoring systems and collect and analyze samples from these systems and collect and analyze samples from these systems in the manner and frequency specified in § 250.43-8;

(iii) Shall maintain surveyed bench marks;

(iv) Shall maintain and monitor the gas collection and control system where such a system is installed to control the vertical and horizontal escape of gases; and

(v) Shall restrict access to the landfill as appropriate for its post-closure use.

NOTE.—The owner or operator of a landfill may request that certain post-closure requirements be discontinued earlier than 20 years after closure. The facility owner or operator shall submit information to the Regional Administrator to indicate that such post-closure care need not continue; (e.g., no leaks have been detected, technology has advanced, alternate disposal techniques are to be employed.) The Regional Administrator shall have the discretion to allow discontinuance of one or more of these post-closure requirements.

(2) No buildings intended for habitation shall be constructed over a landfill where radioactive waste as listed in Subpart A has been disposed.

§ 250.45-3 Surface impoundments.

(a) *Site selection.* (1) A surface impoundment shall be located, designed, constructed, and operated to prevent direct contact between the surface impoundment and navigable water.

(2) A surface impoundment shall be located, designed, and constructed so that the bottom of its liner system or natural in-place soil barrier is at least 1.5 meters (5 feet) above the historical high water table.

NOTE.—The bottom of any liner system or natural in-place soil barrier may be located less than 1.5 meters (5 feet) above the historical high water table provided the owner/operator can demonstrate to the Regional Administrator, at the time a permit is issued pursuant to Subpart E, that no direct contact will occur between the surface impoundment and the water table, and a leachate monitoring system as required in § 250.43-8 can be adequately installed and maintained in the lesser space.

(3) A surface impoundment shall be located at least 150 meters (500 feet) from any functioning public or private water supply or livestock water supply.

NOTE.—A surface impoundment may be located less than 150 meters (500 feet) from any functioning public or private water supply or livestock water supply provided the owner/operator can demonstrate to the Regional Administrator, at the time a permit is issued pursuant to Subpart E, that:

(i) No direct contact will occur between the surface impoundment and any functioning public or private water supply or livestock water supply;

(ii) No mixing of the leachate (including groundwater or surface water contaminated with leachate) with the public or private water supply or livestock water supply will occur; and

(iii) A groundwater monitoring system as required by § 250.43-8 has been installed and is being adequately maintained.

(4) A surface impoundment shall be located, designed, constructed, and operated to minimize landslides, slumping, and erosion.

(b) *Hazardous waste suitable for surface impoundments.* (1) A surface impoundment shall not be used to contain hazardous waste which is:

(i) Detrimental to any material being used as a barrier to the waste movement from the surface impoundment,

(ii) Ignitable waste, as defined in § 250.13(a) of Subpart A,

(iii) Reactive waste, as defined in § 250.13(c) of Subpart A, or

(iv) Volatile waste.

NOTE.—(Relative to ii, iii, and iv) see Note associated with § 250.45(c).

(2) Hazardous waste which is incompatible (see Appendix I) shall not be emplaced together in a surface impoundment.

(3) All hazardous waste shall be tested, prior to placement in a surface impoundment, for compatibility with the intended liner materials to determine whether it will have any detrimental effect (e.g., cause cracks, dissolution, decrease mechanical strength, or increase permeability) on the soils or lining materials used to prevent leakage from the surface impoundment.

(c) *Design and construction.* (1) A surface impoundment shall be designed and constructed so as to be capable of preventing discharges or releases to the groundwater or navigable water.

(2) Where natural geologic conditions allow, a surface impoundment shall have a natural in-place soil barrier on the entire bottom and sides of the impoundment. This barrier shall be at least 3 meters (10 feet) in thickness and composed of natural in-place soil which meets the specifications of paragraph (c)(4).

NOTE.—An owner/operator of a surface impoundment may use a natural in-place soil barrier of different thicknesses and different specifications if the owner/operator can demonstrate to the Regional Administrator, at the time a permit is issued pursuant to Subpart E, that equivalent or greater waste containment can be achieved. However, under no circumstances shall the thickness of the natural in-place soil barrier be less than 1.5 m (5 feet), or its permeability be greater than 10^{-7} cm/sec.

(3) Where geologic conditions do not allow use of the design in paragraph (c)(2), a surface impoundment shall have a liner system covering the entire bottom and sides of the impoundment. This liner system shall consist of top liner, a bottom liner and a leachate detection system which meet the following specifications:

(i) The top liner shall consist of emplaced soil at least 30 centimeters (12 inches) in thickness which meets the criteria in paragraph (c)(4), or an artificial liner which meets the criteria in paragraph (c)(5).

(ii) The bottom liner shall consist of natural in-place soil or emplaced soil which meets the criteria in paragraph (c)(4) and is at least 1.5 meters (5 feet) in thickness, or an artificial liner which meets the criteria in (c)(5).

(iii) The leachate detection system shall be a gravity flow drainage system installed between the top and bottom liners and shall be capable of detecting any leachate that passes through the top liner. Provisions shall be made for pumping out any leachate that passes through the top liner and for removal of noxious gases that occur in the system.

NOTE.—An owner/operator may use a different design if he can demonstrate that an equivalent or greater degree of waste containment is achieved. The Regional Administrator shall take into account the length of time the surface impoundment has been in existence, projected facility life, and artificial liner, natural in-place soil, or emplaced soil permeability and thickness when arriving at a decision regarding whether an equivalent degree of containment exists. In the case of existing facilities, the facility owner/operator may conduct leachate (zone of aeration) monitoring to determine whether any significant increase in the background levels of chemical species has occurred. If no significant increase is observed, the design shall be considered to provide the same or greater degree of performance.

(4) Soils used for surface impoundment liners or natural in-place soil barriers shall:

(i) Be classified under the Unified Soil Classification Systems as CL, CH, SC, or OH, (ASTM Standard D2487-69);

(ii) Allow more than 30 percent passage through a No. 200 sieve (ASTM Test D1140);

(iii) Have a liquid limit equal to or greater than 30 (ASTM Test D423);

(iv) Have a plasticity index equal to or greater than 15 (ASTM Test D424);

(v) Have a pH of 7.0 or higher (See Appendix IV);

(vi) Have a permeability equal to or less than 1×10^{-7} cm/sec. (ASTM Test D2434); and

(vii) Have a permeability not adversely affected by the waste to be placed in the impoundment.

NOTE.—Soil not meeting the above criteria may be used provided that the owner/operator can demonstrate to the Regional Administrator, at the time a permit is issued pursuant to Subpart E, that such soil will provide equivalent or greater structural stability and waste containment properties and will not be adversely affected by the waste to be placed in the impoundment.

(5) Artificial liners for surface impoundments (e.g., concrete, plastic) shall:

(i) Be of sufficient strength to insure mechanical integrity;

(ii) Have a minimum thickness of 30 mils;

(iii) Be compatible with the waste to be placed in the impoundment;

(iv) Have a permeability less than or equal to 1×10^{-7} cm/sec.;

(v) Have an expected service life at least 25 percent longer than the expected time of facility usage;

(vi) Be placed on a stable base;

(vii) Satisfactorily resist attack from ozone, ultraviolet rays, soil bacteria, and fungus;

(viii) Have ample weather resistance to withstand the stress of freezing and thawing;

(ix) Have adequate tensile strength to elongate sufficiently and withstand the stress of installation and/or the use of machinery or equipment;

(x) Resist laceration, abrasion and puncture from any matter that may be contained in the fluids it will hold;

(xi) Be of uniform thickness, free of thin spots, cracks, tears, blisters, and foreign particles; and

(xii) Be easily repaired.

(6) To prevent their rupture, all artificial liners in a surface impoundment where mechanical equipment is used for operation (e.g., sludge dredging and collecting) shall have a protective

cover of selected clean earth material, not less than 45 centimeters (18 inches) thick, placed directly on top of the liner.

(7) A surface impoundment shall have a groundwater monitoring system and a leachate monitoring system that meet the specifications in § 250.43–8.

(8) All surface impoundment dikes shall be designed and constructed in a manner that will prevent discharge or release of waste from the facility, both horizontally and vertically.

(9) All earthen dikes at the facility shall be constructed of clay-rich soil with a permeability less than or equal to 1×10^{-7} cm/sec.

(10) All earthen dikes shall have an outside protective cover (e.g., grass, shale, rock) to minimize erosion by wind and water.

(11) Those surface impoundments which are intended to be closed without removing the hazardous waste shall meet the landfill requirements under Section 250.45–2.

(d) *Operation and maintenance.* (1) A surface impoundment shall be operated and maintained so that discharges or releases to groundwater and navigable water do not occur.

(2) The freeboard maintained in a surface impoundment shall be capable of containing rainfall from a 24-hour, 25-year storm but shall be no less than 60 centimeters (2 feet).

(3) Records shall be kept of the contents and location of each surface impoundment. These records shall be maintained as specified in § 250.43–5(b).

(4) The integrity of the natural in-place soil barrier or the liner system installed in a surface impoundment shall be maintained until closure of the impoundment. The liner system or natural in-place soil barrier shall be repaired immediately upon detection of any failure (e.g., liner puncture).

(5) Surface impoundment dikes shall be visually inspected daily, as specified under Section 250.43–6, for the purpose of detecting and correcting any deterioration. Any maintenance or corrective action necessary to restore the dike to its original condition shall be accomplished expeditiously.

(6) Any system provided for detecting the failure of a liner system or natural in-place soil barrier shall be visually inspected daily, as specified in § 250.43–6, to insure that it is operating properly for the purpose intended.

(e) *Closure and post-closure.* (1) Upon final close-out, all hazardous waste and hazardous waste residuals shall be removed from the surface impoundment, if the impoundment does not meet the landfill requirements under § 250.45–2, and disposed of as hazardous waste pursuant to the requirements of this Part.

(2) Upon final close-out of a surface impoundment which meets the criteria for landfills under § 250.45–2, all hazardous waste and hazardous waste residuals shall be:

(i) Removed and disposed as hazardous waste pursuant to the requirements of this Part, or

(ii) Treated in the impoundment pursuant to the note following § 250.45–2(b) (6) (iv), and then the impoundment shall be closed according to the closure requirements for landfills under § 250.45–2(c).

(3) Emptied surface impoundments shall be filled with an inert fill material and seeded with a suitable grass or ground cover crop, or converted to some other acceptable use that meets the requirement under § 250.43–7.

(4) Those surface impoundments which were closed as landfills shall meet all post-closure requirements for landfills under § 250.45–2(d).

§ 250.45–4 Basins.

(a) A basin shall be constructed of impermeable materials of sufficient strength and thickness to ensure mechanical integrity and to prevent the discharge of waste to navigable waters or groundwater.

(b) A basin shall not be used to contain hazardous waste which is:

(1) Detrimental to the basin's construction materials;

(2) Ignitable waste, as defined in § 250.13(a) of Subpart A;

(3) Reactive waste, as defined in § 250.13(c) of Subpart A; or

(4) Volatile waste.

NOTE.—With respect to (b) (2, 3 and 4), see Note associated with § 250.45(c).

(c) Hazardous waste which is incompatible (see Appendix I) shall not be placed together in a basin.

(d) A hazardous waste shall be tested prior to placement in a basin to determine whether it will have any detrimental effect (e.g., cause dissolution or corrosion, increase permeability, decrease mechanical strength) on materials used for construction of the basin.

(e) The materials used for construction of basins shall be compatible with the hazardous waste and treatment chemicals to be used under expected operating conditions (i.e., temperature, pressure) or shall be protected by a liner compatible with the hazardous waste and treatment chemicals to be

used under expected operating conditions.

(f) A basin shall be monitored or visually inspected daily in accordance with the requirements under § 250.43-6 for leaks, corrosion, cracks, or other damages. Any damage detected shall be repaired immediately.

(g) A basin shall have a groundwater monitoring system meeting the specifications of § 250.43-8.

NOTE.—A basin does not need a groundwater monitoring system if the facility owner/operator can demonstrate to the Regional Administrator, at the time a permit is issued pursuant to Subpart E, that any leaking can be detected by visual inspection or other means.

(h) At final closure, all hazardous waste and hazardous waste residues shall have been removed from a basin and disposed of as hazardous waste pursuant to the requirements of Subparts B, C, and D.

250.45-5 Landfarms.

(a) *Hazardous waste not amenable to landfarming.* The following hazardous waste shall not be landfarmed:

(1) Ignitable waste, as defined in § 250.13(a) of Subpart A;

(2) Reactive waste, as defined in § 250.13(c) of Subpart A;

(3) Volatile waste;

(4) Waste which is incompatible when mixed (see Appendix I).

NOTE.—See Note associated with § 250.45(c).

(b) *General requirements.* (1) A landfarm shall be located, designed, constructed, and operated to prevent direct contact between the treated area and navigable water.

(2) A landfarm shall be located, designed, constructed, and operated to minimize erosion, landslides, and slumping in the treated area.

(3) A landfarm shall be located, designed, constructed and operated so that the treated area is at least 1.5 meters (5 feet) above the historical high water table.

NOTE.—The treated area may be located less than 1.5 meters (5 feet) above the historical high water table if the owner/operator can demonstrate to the Regional Administrator, at the time a permit is issued pursuant to Subpart E, that no direct contact will occur between the treated area and the water table.

(4) The treated area of a landfarm shall be at least 150 meters (500 feet) from any functioning public or private water supply or livestock water supply.

NOTE.—The treated area of a landfarm may be less than 150 meters (500 feet) from any functioning public or private water supply or livestock water supply, provided the facility owner/operator can demonstrate to the Regional Administrator, at the time a permit is issued pursuant to Subpart E, that:

(i) No direct contact will occur between the treated area of the landfarm and any functioning public or private water supply or livestock water supply;

(ii) No migration of hazardous constituents from the soil in the treated area of the landfil to any public or private water supply or livestock water supply will occur; and

(iii) A soil monitoring system as specified in § 250.45-5(e) has been installed and is being adequately maintained.

(5) A landfarm shall be located on an area that has fine grained soils (i.e., more than half the soil particles are less than 73 microns in size which are of one of the following types, as defined by the Unified Soil Classification System (ASTM Standard D 2487-69): OH—organic clays of medium to high plasticity; CH—inorganic clays of high plasticity, fat clays; MH—inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts; CL—inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays; OL—organic silts and organic silt-clays of low plasticity.

NOTE.—A landfarm may be located on an area with soil types other than those specified above provided the owner/operator can demonstrate to the Regional Administrator, at the time a permit is issued pursuant to Subpart E, that the alternative soil types will prevent hazardous constituents from vertically migrating a distance that exceeds three times the depth of the zone of incorporation or 30 centimeters (12 inches), whichever is greater.

(c) *Site preparation.* (1) Surface slopes of a landfarm shall be less than 5 percent, to minimize erosion in the treated area by waste or surface run-off, but greater than zero percent to prevent the waste or water from ponding or standing for periods that will cause the treated area to become anaerobic.

NOTE.—Surface slopes of the landfarm may be greater than 5 percent provided the owner/operator can demonstrate to the Regional Administrator, at the time a permit is issued pursuant to Subpart E, that such slopes will not result in erosion caused by waste or surface run-off in the treated area.

(2) Caves, wells (other than active monitoring wells), and other direct connections to the subsurface environment within the treated area of a landfarm, or within 30 meters (100 feet) thereof, shall be sealed.

(3) Soil pH in the zone of incorporation shall be equal to or greater than 6.5 (see Appendix IV).

NOTE.—Soil pH in the zone of incorporation may be less than 6.5 provided the owner/operator can demonstrate to the Re-

gional Administrator, at the time a permit is issued pursuant to Subpart E, that hazardous constitutents, especially heavy metals, will not migrate vertically a distance that exceeds three times the depth of the zone of incorporation or 30 centimeters (12 inches), whichever is greater.

(d) *Waste application and incorporation.* (1) Waste application and incorporation practices shall prevent the zone of incorporation from becoming anaerobic.

(2) Waste shall not be applied to the soil when it is saturated with water.

NOTE.—Waste may be applied to the soil when it is saturated with water provided the owner/operator can demonstrate to the Regional Administrator, at the time a permit is issued pursuant to Subpart E, that the soil-waste mixture will remain aerobic and that hazardous constituents, especially heavy metals, will not migrate vertically a distance that exceeds three times the depth of the zone of incorporation or 30 centimeters (12 inches), whichever is greater.

(3) Waste shall not be applied to the soil when the soil temperature is less than or equal to 0° C.

(4) The pH of the soil-waste mixture in the zone of incorporation shall be equal to or greater than 6.5 and maintained until the time of facility closure.

NOTE.—The pH of the soil-waste mixture in the zone of incorporation may be less than 6.5 provided the owner/operator can demonstrate to the Regional Administrator, at the time a permit is issued pursuant to Subpart E, that hazardous constituents, especially heavy metals, will not vertically migrate a distance that exceeds three times the depth of the zone of incorporation or 30 centimeters (12 inches), whichever is greater.

(5) Supplemental nitrogen and phosphorous added to the soil of the treated area, for the purpose of increasing the rate of waste biodegradation, shall not exceed the rates of application recommended for agricultural purposes by the United States Department of Agricultural or Agricultural Extension Service.

(e) *Soil monitoring.* (1) Background soil conditions shall be determined by taking one soil core per acre in the area to be treated. The depth of the soil core shall be three times the depth of the zone of incorporation or 30 centimeters (12 inches), whichever is greater. The bottom one-third of the soil core shall be quantitatively analyzed for those constituents known or expected to be in the waste which make it hazardous. At new facilities, soil cores shall be taken and analyzed prior to beginning operation. At existing facilities, background soil cores shall be taken and analyzed within six months after the effective date of these regulations.

(2) Soil conditions in the treated area of a landfarm shall be determined by taking one soil core per acre, semi-annually. The depth of the soil core shall be three times the depth of the zone of incorporation or 30 centimeters (12 inches), whichever is greater. The bottom one-third of the soil core shall be quantitatively analyzed for the constituents in the waste which make it hazardous.

NOTE.—Soil monitoring may be conducted by taking less than one soil core per acre and/or by monitoring less frequently than semi-annually, provided the owner/operator can demonstrate to the Regional Administrator, at the time a permit is issued pursuant to Subpart E, that hazardous constituents, especially heavy metals, will be detected before vertically migrating a distance that exceeds three times the depth of the zone of incorporation or 30 centimeters (12 inches), whichever is greater.

(3) If soil monitoring shows that the concentration of a hazardous constituent in the bottom one-third of the soil core has significantly exceeded the background levels established in accordance with paragraph (e)(1), the owner/operator shall: (i) Notify the Regional Administrator within seven days;

(ii) Determine, by soil monitoring, the areal extent of vertical contaminant migration in the soil; and

(iii) Discontinue all landfarming in the contaminated area, as determined in (ii), until corrective measures can be taken.

(f) *Growth of food-chain crops.* Food-chain crops shall not be grown on the treated area of a landfarm.

(g) *Closure.* (1) A landfarm shall be designed and operated so that, by the time of closure, the soil of the treated area(s):

(i) Is returned to its pre-existing condition, as established in paragraph (e)(1) if the facility began operation after promulgation of this requirement (i.e., a new facility).

(ii) Is returned to equivalent pre-existing condition, as determined by soil analysis of similar local soils that have not had hazardous waste applied to them, if the facility began operation prior to the promulgation of this requirement (i.e., an existing facility). Soil analysis of similar local soils shall not be required at existing facilities if background soil data are available and those data establish background conditions for the treated area(s).

(2) Soil of the treated area(s) of a new or existing facility that does not comply with paragraph (g)(1)(i) or (ii),

respectively, shall be analyzed to determine if it meets the characteristics of a hazardous waste as defined in Subpart A. In the event the soil is determined to be a hazardous waste, it shall be removed and managed as a hazardous waste in accordance with all applicable requirements of this Part.

NOTE.—The soil at a landfarm, if determined to be a hazardous waste, need not be removed provided the owner/operator can demonstrate to the Regional Administrator that, because of its special design and/or because of its location, the landfarm provides long term integrity and environmental protection equivalent to a landfill as specified in § 250.45-2. In the event of such a showing, the owner/operator shall comply with the applicable closure and post-closure provisions of § 250.43-7 and 250.45-2(c and d).

§ 250.45-6 Chemical, physical, and biological treatment facilities.

(a) The materials used in construction of the treatment facility shall be compatible, under expected operating conditions (e.g., temperature, pressure), with the hazardous waste and any treatment chemicals or reagents used in the treatment process.

(b) The hazardous waste shall be analyzed, as appropriate, prior to selection of a treatment technique to determine:

(1) The proper treatment technique, the proper feed rates of treatment chemicals or reagents, and the proper operating conditions (e.g., temperature, pressure, flow rate);

(2) If the waste or treatment chemicals or reagents will have any detrimental effect (e.g., cause corrosion, dissolution, saltings or scalings) on the materials used for construction;

(3) If the waste contains any components or contaminants which may interfere with the intended treatment process (e.g., biological treatment, solidification, adsorption processes) or decreases the effectiveness of the treatment;

(4) If the waste contains components or contaminants which may cause the uncontrolled release of toxic gases or fumes (e.g., H_2S, HCN) during the intended treatment;

(5) If the waste contains components or contaminants which may form highly toxic components with the treatment chemicals or reagents (e.g., halogenated hydrocarbons) during the intended treatment.

NOTE.—The analyses of hazardous waste may be omitted provided the owner/operator can demonstrate to the Regional Administrator that the information provided in the manifest is adequate to make the determinations required in paragraph (b), or the facility owner/operator has sufficient information documenting that the subject hazardous waste is similar to a hazardous waste which has been previously treated at the facility where the same treatment conditions and the same treatment chemicals or reagents were used.

(c) Trial tests (bench scale, pilot plant scale, or other appropriate tests) shall be performed for each hazardous waste which is new or significantly different from hazardous waste previously treated to determine treatment technique and operating conditions, and to evaluate the effectiveness of the treatment process and consequences of the proposed treatment.

(d) All treatment chemicals or reagents used in a treatment process shall be stored in such a manner as to minimize the potential for spills, fires, explosions, or uncontrolled discharges or releases.

(e) All uncovered reaction vessels shall be sized to provide no less than 60 centimeters (2 feet) freeboard to prevent splashing or spillage of hazardous waste during the treatment (e.g., neutralization, precipitation).

(f) A facility shall have the capacity to receive emergency transfer of reactor contents, or shall have emergency storage capacity to be used in the event of an equipment breakdown or malfunction.

(g) A facility which continuously feeds hazardous waste into the treatment process shall be equipped with an automatic waste food cutoff or a by-pass system which is activated when a malfunction in the treatment process occurs.

(h) Upon final closure, all hazardous waste and hazardous waste residuals shall be removed from the facility, and treated or disposed of as hazardous waste pursuant to the requirements of this Part.

(i) All residuals or by-products from a treatment process (e.g., sludges, spent resins) shall be analyzed to determine whether they are hazardous waste within the meaning of Subpart A, or assumed to be a hazardous waste.

NOTE.—Analyses of treatment residuals or by-products may be omitted provided the owner/operator can demonstrate that the subject residuals and/or by-products are similar to those previously produced at the facility.

TABLE B-1. CAPITAL UNIT COST FILE

Code	Mnemonic	Cost Equation Coefficients* A	B	C	D	Description	Units	Source Code†
1	GENER	0.0	4000	1.0	1.0	Electric Generator	ea	1
2	COMEQ	0.0	500	1.0	1.0	Communications Equipment	ea	1
3	WTRK	0.0	20000	1.0	1.0	Water Truck	ea	1
4	FKLFT	0.0	20000	1.0	1.0	Fork Lift	ea	1
5	FELDR	0.0	70000	1.0	1.0	Front End Loader	ea	1
6	TKDZR	0.0	100000	1.0	1.0	Track Dozer	ea	1
7	PUTRK	0.0	10000	1.0	1.0	Pickup Truck	ea	1
8	WTANK	0.0	10000	1.0	1.0	10000 Gal Water Tank	sf	1
9	LNRCL	0.0	2.09	1.0	1.0	Liner with clay layer	lf	1
10	LEACH	0.0	6.10	1.0	1.0	Leachate collection system	ea	1
11	GWMON	0.0	600	1.0	1.0	Ground water monitor (well)	ea	1
12	PLDSN	0.0	75000	1.0	1.0	Planning and design	ft	1
13	ROAD1	0.0	214.90	1.0	1.0	Permanent access road	ft	1
14	ROAD2	0.0	64.31	1.0	1.0	Temporary access road	ft	1
15	ETHWL	0.0	7.20	1.0	1.0	Earth Wall	ea	1
16	DBASN	0.0	3000	1.0	1.0	Debris Basin	ft	2
17	FENCE	0.0	8.10	1.0	1.0	Industrial chainlink fence 6'	sf	2
18	LFOFF	0.0	48	1.0	1.0	Office Building	sf	1
19	STOR1	0.0	31	1.0	1.0	Maintenance Storage	sf	1
20	STOR2	0.0	31	1.0	1.0	PCB storage	lf	1
21	CLEXC	0.0	1.31	1.0	1.0	Landfill clear/excavate	lf	1
22	PIPE1	0.0	246	1.0	1.0	Corrugated metal pipe 30"	lf	2
23	PIPE2	0.0	8.80	1.0	1.0	2" perforated feed pipe	lf	2
24	PIPE3	0.0	32.09	1.0	1.0	6" Discharge pipe	lf	2
25	PIPE4	0.0	32.09	1.0	1.0	6" Sludge pipe	lf	2
26	PIPE5	0.0	21.42	1.0	1.0	3" Pipe and connectors	Dia"	2
27	PIPE6	9.3	3.955	1.0	1.0	Industrial steel pipe	sf	3
28	LINER	0.0	.44	1.0	1.0	Pond Liner	ea	4
29	AER50	0.0	14000	1.0	1.0	50 HP Aerator	hp	4
30	AERSS	52940	277914	1.75	1.0	Stainless steel aerator	hp	4
31	AERCS	88211	21009	1.5	1.0	Carbon Steel Aerator	ea	5
32	GATE	0.0	120	1.0	1.0	14" Slide Gate	lf	6
33	WEIR	0.0	60.	1.0	1.0	Overflow Weir		

(Continued)

See footnotes at end of table.

TABLE B-1. (Continued)

Code	Mnemonic	Cost Equation Coefficients* A	B	C	D	Description	Units	Source Code†
36	CSAST	0.0	101.52	1.0	1.0	Cylinder safety stand	ea	8
37	PRTNK	1.6867E11	3.9413E07	3.0	2.0	Pressurized tank	gal	9
38	CSPLT	0.0	1.15	1.0	1.0	Coated carbon steel platewk	lbs	010
39	SSPL1	0.0	2.40	1.0	1.0	Stainless platework diam<10	lbs	010
40	SSPL2	0.0	3.00	1.0	1.0	Stainless platework 10<dia<12	lbs	010
41	SSTSH	36.4	105.33	1.5	1.0	Stainless steel tank shell	gal	010
42	ACOMP	0.0	1409	1.0	1.0	Air Comp 1-3-28 ISCFMA+80PSIG	ea	011
43	AFLTT	28.22	195.4	1.0	1.0	Air Flotation (Tank) *1000$	sf	012
44	ARFLT	5.9420	0.30668	7.0	5.0	Air Flotation (no tank)*1000$	sf	012
45	ULTFL	7.487E09	2.008E05	2.0	2.0	Ultrafiltration	gpm	013
46	OSMOS	20947	334.08	1.0	1.0	Reverse osmosis	gpm	013
47	BUILD	7.0496	3.991	1.0	1.0	Building shell	sf	002
48	DEARA	6.6348E09	24799.2	2.5	2.0	Dearator	gpm	014
49	MEDIA	0.0	2.50	1.0	1.0	Trickling filter media	cf	015
50	LAND	0.0	.744	1.0	1.0	Land	sf	010
51	HEAT	17960	0.02468	1.0	1.0	Sludge Heater	btu	016
52	INCIN	90000	5073	1.0	1.0	Incinerator incl. aftrbrn&scrb.	lbs/hr	010
53	GASCO	0.0	8982	1.0	1.0	Digestor gas control system	ea	017
54	COVER	5.0983	0.017156	1.0	2.0	Digestor cover *1000$	dia '	016
55	PUMP1	1400	6.5	1.0	1.0	Chemical addition pump	gpm	009
56	PUMP2	-125	9.23	1.0	1.0	Sludge pump	gpm	018
57	PUMP3	1000	1.953	1.0	1.0	Liquid waste pump	gpm	018
58	SLAKE	18700	2.14	1.0	1.0	Lime slaker	lbs/hr	019
59	VIBFD	3.0594E08	1.4381E06	3.0	2.0	Vibratory feeder	tons sand/hr	020
60	VESS1	39413003	393305	2.0	1.0	Glass Reactor Ves w/o mixer	gal	021
61	VESS2	1.4966E08	872968	2.0	1.0	Glass Reactor ves with mixr	gal	021
62	DIMIX	17413	183.4	1.0	1.0	Digestor mix & gas recirc.	dia'	016
63	TROUG	0.0	1	1.0	1.0	Washwater troughs	*	006
64	SLCOL	14100	121.43	1.0	1.0	Sludge Collector (10' x 20'XL)	ft	022
65	CLARI	0.0	1025	3.5	1.0	Clarifier skimmer scum box	dia'	022
70	RDVAC	2720.5	62.055	2.0	1.0	Rotary Drum vacuum fil *1000$	sf	012

(Continued)

TABLE B-1. (Continued)

Code	Mnemonic	Cost Equation Coefficients* A	B	C	D	Description	Units	Source Code†
71	DISTR	8.142	0.22458	1.0	1.0	Rotary distributor-tri *1000$	ft	015
72	OFFIC	0.0	38.88	-1.258-04	1.0	Office	sf	2
73	RLABS	0.0	65.56	-1.005-04	1.0	Small research labs	sf	2
74	FLOCP	0.0	5000.	1.0	1.0	Floculator paddle	ea	026
75	STGEN	11000	2.89	1.0	1.0	Steam generator	lbs/hr	027
76	COAG	1700	171.57	1.0	1.0	Coag Blender	(width) in	006
77	PLATE	0.0	90.20	1.0	1.0	Oil/water sep plates stk	ft	028
78	EVAP	2787.8	67.545	1.5	1.0	Spray film evaporator *1000$	gpm	029
79	CKVLV	156.94	13.263	1.0	1.0	Check Valve	dia"	2
80	CLR1	0.0	.05	1.0	1.0	Clearing surface only	sf	2
81	CLR2	0.0	.84	1.0	1.0	Clearing surface & subsurface	sf	2
82	GRADE	0.0	.025	1.0	1.0	Grading	sf	2
83	EXCV1	0.0	2.12	1.0	1.0	Excavation struct. w/hauling	cy	2
84	EXCV2	0.0	5.88	1.0	1.0	Excavation footings & piers	cy	2
85	EXCV3	0.0	1.82	1.0	1.0	Excavation struct. w/site disp.	cy	2
86	BKFL1	0.0	.06	1.0	1.0	Backfill dozer spread	cy	2
87	BKFL2	0.0	6.41	1.0	1.0	Backfill spread & compacted	cy	2
88	PAVE	0.0	.92	1.0	1.0	Paving 3" asphalt on 8" rock	sf	2
89	FOUN1	0.0	12	1.0	1.0	Pile foundations-drecast	lf	2
90	FOUN2	0.0	16	1.0	1.0	Pile foundations-steel "H"	lf	2
91	FOUN3	0.0	21	1.0	1.0	Pile foundations-pipe	lf	2
92	FOUN4	0.0	7.5	1.0	1.0	Pile foundations-wood	lf	2
93	SLAB1	0.0	154	1.0	1.0	Concrete base slab	cy	2
94	SLAB2	0.0	78.92	1.0	1.0	Concrete base slab 6" rein/cip	cy	2
95	WALL1	0.0	240	1.0	1.0	8' concrete 10" dbl curtain rein	cy	2
96	WALL2	0.0	221	1.0	1.0	8' & up concrete 10" dbl curtain	cy	2
97	WALL3	0.0	210	1.0	1.0	8' concrete 6" sgl curtain cip	cy	2
98	WALL4	0.0	200	1.0	1.0	8' & up concrete 6" sgl curtain	cy	2
99	WALL5	0.0	229	1.0	1.0	8' concrete 8" sgl curtain rein	cy	2
100	WALL6	0.0	226	1.0	1.0	8' & up concrete 8" sgl curtain	cy	2
101	WDBM1	0.0	.7	1.0	1.0	Doug. Fir pres trtd 4" x 12"	bdft	2
102	WDBM2	0.0	.9	1.0	1.0	Coug. Fir pres trtd 6" x 10"	bdft	2

(Continued)

TABLE B-1. (Continued)

Code	Mnemonic	Cost Equation Coefficients A	B	C	D	Description	Units	Source Code†
103	WDDK	0.0	.54	1.0	1.0	Redwood wood decking	bdft	2
104	HNDRL	0.0	15.36	1.0	1.0	1-½" aluminum handrail	lf	2
105	SONO	0.0	225	1.0	1.0	12" rnd. sonotubecip anchr.	cy	2
106	KILN	135939	5616.8	1.4	1.0	Rotary kiln incinerator	lbs/hr	031
107	HEART	15312	35.525	1.5	1.0	Multiple hearth incinerator	lbs/hr	013
108	CONDE	5.0469E09	5.0398E08	2.5	1.0	Condensor	gpm	031
109	REBOI	2923281	21091	1.5	1.0	Reboiler	sf	031
110	EXCHA	1863624	13446	1.5	1.0	Heatexchanger	sf	031
111	OILWA	50035	384.36	1.5	1.0	Oil water separator tank	lbs	028
112	VAPOR	0.0	3500.	1.0	1.0	Chlorinator	ea	032
113	DISTL	490000.	2300.	1.0	1.0	Distillation column-50 trays	ea	031
114	MOTOR	30.	14.	1.0	1.0	Elec drive mtr-1800RPM-no str	hp	002
115	ACCAR	0.0	.40	1.0	1.0	Activated carbon	lb	091
116	VAULT	0.0	2800.	1.0	1.0	Utility vault	ea	002
117	COAL	0.0	126.45	1.0	1.0	Anthracit coal filter media	cy	034
118	SAND	0.0	388.42	1.0	1.0	Silica sand	cy	034
119	STRST	0.0	0.6	1.0	1.0	Structural steel framework	lb	002
120	FTANK	1466.	0.39	1.0	1.0	Fiberglass tank	gal	041
121	ENCAP	0.0	75.	1.0	1.0	Encapsulation equipment	tons/yr	046

*Cost = $(A+B\times units^{D})^{(1/c)}$.
†See source list in Volume 1.

TABLE C-1. OPERATION AND MAINTENANCE UNIT COST FILE

Code	Mnemonic	Cost Equation Coefficients* A	B	C	D	Description	Units	Source Code†
1	WATER	0.0	0.026	1.0	1.0	Chicago water rate	gal	33
4	POWER	0.0	.035	1.0	1.0	Chicago electrical rate	kwh	35
5	OPER1	0.0	7.77	1.0	1.0	Operator level 1	hr	50
6	OPER2	0.0	9.19	1.0	1.0	Operator level 2	hr	50
7	LABOR	0.0	6.76	1.0	1.0	Laborer	hr	50
8	MECH1	0.0	9.40	1.0	1.0	Maintenance mechanic 1	hr	50
9	MECH2	0.0	11.20	1.0	1.0	Maintenance mechanic 2	hr	50
10	ELEC1	0.0	9.99	1.0	1.0	Electrician 1	hr	50
11	ELEC2	0.0	11.75	1.0	1.0	Electrician 2	hr	50
12	HELPR	0.0	7.70	1.0	1.0	Maintenance helper	hr	50
13	SUPER	0.0	12.94	1.0	1.0	Maintenance supervisor	hr	50
14	FORMA	0.0	12.45	1.0	1.0	Mechanical maintenance foreman	hr	50
15	PAINT	0.0	9.05	1.0	1.0	Painter	hr	50
16	STRKP	0.0	6.43	1.0	1.0	Storekeeper	hr	50
17	CUSTO	0.0	6.76	1.0	1.0	Custodian	hr	50
18	SPTNT	0.0	18.32	1.0	1.0	Superintendent	hr	50
19	ASSPT	0.0	15.37	1.0	1.0	Asst. superintendent	hr	50
20	OPSUP	0.0	12.21	1.0	1.0	Operations Supervisor	hr	50
21	SHFOR	0.0	9.19	1.0	1.0	Shift foreman	hr	50
22	AUTO	0.0	8.75	1.0	1.0	Automotive equipment operator	hr	50
23	CHEM	0.0	8.51	1.0	1.0	Chemist	hr	50
24	LABTE	0.0	7.33	1.0	1.0	Lab technician	hr	50
25	CLERK	0.0	6.03	1.0	1.0	Clerk/typist	hr	50
26	ALSU1	0.0	0.045	1.0	1.0	17% AL203 bags	lb	48
27	ALSU2	0.0	0.042	1.0	1.0	17%AL203 bulk	lb	48
28	ALSU3	0.0	0.27	1.0	1.0	3% AL203 liquid	lb	48
29	CAO1	0.0	0.013	1.0	1.0	Calcium oxide 93%-98% bulk	lb	48
30	CAO2	0.0	0.017	1.0	1.0	Calcium oxide 93%-98% bags	lb	48
31	CAHY1	0.0	0.015	1.0	1.0	Calcium hydroxide 72-74% bulk	lb	48
32	CAHY2	0.0	0.017	1.0	1.0	Calcium hydroxide 72-74% bags	lb	48
33	FECL3	0.0	0.44	1.0	1.0	Ferric Chloride liquid	gal	48
34	COACL	0.0	3.31	1.0	1.0	Calcium hypochlorite drums	gal	48

(Continued)

See footnotes at end of table.

TABLE C-1. (Continued)

Code	Mnemonic	Cost Equation Coefficients* A	B	C	D	Description	Units	Source Code†
35	FUEL	0.0	.61	1.0	1.0	#2 diesel fuel 1979 figure	gal	010
36	NGAS	0.0	3.475-03	1.0	1.0	Natural gas 1979 figure	cf	049
37	DMPWT	0.0	148	1.0	1.0	Dumping fee disposal site	ton	
38	POLYM	0.0	0.002	1.0	1.0	Air flotation solid	bs	012
39	GAS	0.0	.85	1.0	1.0	Gasoline	gal	010
40	AMMON	0.0	0.56	1.0	1.0	Liquid ammonia	gal	047
41	PHOS	0.0	0.014	1.0	1.0	Phosphoric acid	gal	044
42	CHFX1	0.0	0.10	1.0	1.0	Chem fix ser. solids <10%	gal	039
43	CHFX2	0.0	0.45	1.0	1.0	Chem fix ser. solids >10%	gal	039
44	INCIN	0.0	0.125	1.0	1.0	Hazardout liq incin. fee	gal	010
45	ACCAR	0.0	0.40	1.0	1.0	Activated carbon	lbs	045
46	DEMUL	0.0	9.58	1.0	1.0	Oil/water demulsifier	gal	042
47	CLBOT	0.0	0.13	1.0	1.0	Chlorine bottles	lbs	040
48	CLCYL	0.0	0.29	1.0	1.0	Chlorine cylinders	lbs	040
49	ENCAP	0.0	89.70	1.0	1.0	Encapsulation service	ton	046
50	CAPCM	0.0	0.44	1.0	1.0	Encapsulation chemicals	ton	046
51	TRUK1	0.20	4.64-03	1.0	1.0	Intrastate trucking	100lb-mile	023
52	TRUK2	0.0	7.90	1.0	1.0	Interstate trucking	100wt	024
53	RAIL1	0.0	6.90	1.0	1.0	Interstate rail Chi-Sea	100wt	025
54	H2SO4	0.0	0.038	1.0	1.0	Sulfuric acid	gal	043

*Cost= $(A+Bx\ Units^{D})^{(1/C)}$.

†See list of sources.

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APPENDIX D

CURVE FITTING FOR COST FILES

In estimating capital and operating costs for the various technology module or module components (Appendices B and C), cost functions were developed to predict component costs for various scaling factors. Although many will be simple linear or multiplicative functions of capacity or throughput, certain special pieces of equipment, in particular, may have other than linear relationships between their costs and their scale. Once costs are determined for the components in Appendices B and C, they are utilized in the module cost equations in Appendix F.

For this reason, a curve fitting methodology has been developed for determining the most appropriate functional form to use. As with most statistical techniques, the use of this methodology requires two things: (1) that an adequate number of cost/size data points be available and (2) that the included data points be from the same population - that is, if the component to be costed is a pump, then the costs data points differ only because of pump size, and not because they are for differing kinds of pumps. Particular emphasis is placed on this last point, and manufacturers were contacted to develop a sufficient number of cost data points for each such special piece of equipment.

The curve fitting methodology involves a series of regression attempts to fit particular cost/size data points to various candidate functional forms. As an absolute minimum, 3 data points are required. But, for practical application of the methodology, more statistically meaningful results are obtained using 5 to 10 data points. Assuming these data points are available, the following functional forms are attempted:

(1) $Y = a + bX$

(2) $e^Y = aX^b \quad Y = \ln(aX^b)$

(3) $\ln Y = a + bX \quad Y = e^{(a + bX)}$

(4) $Y = aX^b$

(5) $Y = a + bX^2$

(6) $Y^2 = a + bX \quad Y = \text{SQRT}\ (a + bX)$

(7) $Y^2 = a + bX^2 \quad Y = \text{SQRT}\ (a + bX^2)$

(8) $Y^c = a + bX^D \quad Y = (a + bX^D)^{\frac{1}{c}}$

(9) $(\ln Y)^c = a + b\ (\ln X)^D \quad Y = e^{((a + b\ (\ln X)^D)^{\frac{1}{c}})}$

(10) $Y = a + bX + cX^2$

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In these equations: Y is the dependent cost variable; X is the independent size variable, and a and b are constants that are using lease-squares technique, estimated as α and β. As example Figure D-1 shows, these equations are special cases of the general form:

$$(\ln Y)^L = A + B\ (\ln X)^M$$

where the natural logs (ln's) are optional; where B is β; and where A may be α or $\ln\alpha$.

After the first seven regressions are performed, the results are analyzed and as many as three additional models may be attempted. In the example, significant F statistics were developed under the first, sixth and seventh forms; but two additional functional forms were tested using an approximation of the B-inverse under Form 4 as the exponent of Y (i.e., 1/0.89332 1.5) and single and squared exponents for X.

Although the seventh and eighth forms in this example proved to be more significant (higher F statistics) with slightly higher percent explanation (i.e., the R^2 coefficients of determination were slightly higher), the simple linear form, Form 1, was chosen for estimating this component's costs as a function of diameter, in feet. The reason for this choice is that Form 1 is adequately significant (at greater than 99 percent confidence) and substantially more simple to use than either Forms 7 or 8. By making this selection, only 2 or 3 percent explanation is sacrificed, but any ultimate comprehension by the reader is substantially enhanced.

If 10 forms are tested for a particular component, and all yield insignificant F statistics, the methodology requires that additional data points be developed before further curve fitting analysis is attempted.

The results of the curve fitting analysis for speciality equipment cost data not demonstrating definite linearity (graphic method) are shown in Table D-1. Table D-2 lists the relevant ranges for the curve fitting result. Where possible, these ranges should not be exceeded.

(m = 16 using program CR)

Comp. Flacq. Clairifier

$\ell ny = A + B\ \ell n\ x$; where ℓn's are optional and A may be $\hat{\alpha}$ or $\ell n\hat{\alpha}$

	Xi in Diameter	Yi in $
1	30	38,600
2	40	46,350
3	45	71,900
4	65	86,300
5	80	96,000
6	85	101,500
7	100	114,100
8		
9		
10		
11		
12		
13		
14		
15		
16		

@ α = .10; Ft = 4.06

@ α = .05; Ft = 6.61

@ α = .01; Ft = 16.26

H_0: $\beta = \emptyset$ can be rejected at the $1 - \alpha$ confidence level if computed F > tabular F for d.f. of 1 for num. and n - 2 for denom.

n = 7

1	$y = \hat{\alpha} + \hat{\beta} X$	L = 1 M = 1		$\hat{\beta}$ = 1054.5 $\hat{\alpha}$ = 12216	R^2 = .9408 R = .96995	F = 38.88
2	$y = \ell n\hat{\alpha} + \hat{\beta}\ell n\ X$ or $e^y = \alpha X^{\hat{\beta}}$	L = 1 M = 1	ℓnX	$\hat{\beta}$ = 62377 $\ell n\hat{\alpha}$ = -174720 $\hat{\alpha} = \emptyset$	R^2 = .9632 R = .9814	F = .3798
3	$\ell nY = \hat{\alpha} + \hat{\beta} X$	L = 1 M = 1	 ℓnX	$\hat{\beta}$ = .014796 $\hat{\alpha}$ = 10.273	R^2 = .8752 R = .9355	F = .02117
4	$\ell nY = \ell n\hat{\alpha} + \hat{\beta}\ell nX$ ie $Y = \hat{\alpha} X^{\hat{\beta}} = \hat{\alpha}^{\frac{1}{\hat{\beta}}} X$	L = 1 M = 1	ℓnX ℓnY	$\hat{\beta}$ = .89332 $\ell n\hat{\alpha}$ = 7.5768 $\hat{\alpha}$ = 1952.5	R^2 = .9335 R = .9662	F = .0415
5	$Y = \hat{\alpha} + \hat{\beta} X^2$	L = 1 M = 2		$\hat{\beta}$ = 7.8859 $\hat{\alpha}$ = 42,778	R^2 = .8854 R = .9409	F = 5.0733
6	$Y^2 = \hat{\alpha} + \hat{\beta} X$ ie $Y = \hat{\alpha} + \hat{\beta} X$	L = 2 M = 1		$\hat{\beta}$ = $1.6164*10^8$ $\hat{\alpha}$ = $-3.3051*10^9$	R^2 = .97496 R = .98740	F = 21.706
7	$Y^2 = \hat{\alpha} + \hat{\beta} X^2$ ie $Y = \hat{\alpha} + \hat{\beta} X^2$	L = 2 M = 2		$\hat{\beta}$ = $1.2313*10^8$ $\hat{\alpha}$ = $1.2754*10^9$	R^2 = .9520 R = .9757	F = 61.28
8	$Y^{1.5} = \hat{\alpha} + \hat{\beta} X$	L = 1.5 M = 1		$\hat{\beta}$ = 434188 $\hat{\alpha}$ = -4,342,401	R^2 = .9624 R = .9810	F = 56.80
9	$Y^{1.5} = \hat{\alpha} + \hat{\beta} X^2$	L = 1.5 M = 2		$\hat{\beta}$ = 3277.7 $\hat{\alpha}$ = 8,100,395	R^2 = .9228 R = .9606	F = 19.13
10		L = M =		$\hat{\beta}$ = $\hat{\alpha}$ =	R^2 = R =	

Figure D-1. Curve fitting worksheet.

TABLE D-1. CURVE FITTING RESULTS

Title	Y-units*	X-units	L	α	β	M	R^2	F	Level of Confidence Sample Size	
Tank - Stainless Steel	$	Gal	1.5	36.40	105.33	1	.9999	91237	3	99+
Ultra Filtration	$	Flow in GPM	2	7.487E9†	2.008E5	2	.998	305.47	4	99+
Air Flotation	1,000's $	Sq. Ft	2	195.4	28.22	1	.986	127.25	4	99+
Reverse Osmosis	$	Gal/Day	1	20947	.696008	1	.998	222	5	99+
Aerators, CFSS & TFNI	$	H. P.	1.5	68211	21009	1	.951	46.41	5	99+
Steel Buildings	1,000's $	1,000's sq.ft	1	7.0496	3.0991	1	.9997	46.92	5	99+
Aerators, SS	$	H. P.	1.75	52940	277919	1	.944	50.44	5	99+
Serfilco Pressurized Tank	$	Gal	3	1.6867E11	3.9413E7	2	.952	42.73	5	99+
Vib. Feeders	$	Ton Sand/Hr	3	3.0594E8	1.4381E6	2	.997	1044	6	99+
Glass R. Vessel W/o Mixer	$	Gal	2	39313003	393305	1	.995	610.8	6	99+
Glass R. Vessel W. Mixer	$	Gal	2	1.4966E8	872968	1	.994	337.16	6	99+
Com. Flacq. Clarifier	1,000's $	Dia. in ft	2.25	2126.2	3.7359	2	.963	104.78	7	99+
RD Vacuume Filter	1,000's $	Sq.Ft Filter area	2	2720.5	62.055	1	.997	313.83	8	99+
Rotory Distributor (Trickling filter)	1,000's $	Tank Dia. in ft	1	8.1420	.22458	1	.997	83.005	10	99+
Gas Holder Dgester Cover	1,000's $	Dia. in ft	1	5.0983	.017156	2	.9999	180.78	4	99+
Air Flotation (w/o tank)	1,000's $	Sq.Ft	7	5.9420	.30668	5	.946	25.48	4	95+
Spray Film Evaporator	1,000's $	Gal/Min.	1.5	2787.8	67.545	1	.999	1342	5	99+
Check Valve	$	Inches Dia.	1	156.94	13.263	2	.996	635.49	9	99+
De Aerator (# 1)	Land Am.in Ft^2	Gal/Min.	1.85	99.831	18.888	1	.990	654.42	9	99+
De Aerator (# 2)	Steam in 1,000's $	Gal/Min	.8	1,1347	.11184	1	.999	4568	9	99+
De Aerator (# 3)	$	Gal/Min.	2.5	6.6348E9	247992	2	.996	851.74	9	99+
Rotary Kiln Incinerator	$	Lbs/Hr	1.4	135939	5616.8	1	.998	1725.19	6	99+
Multiple Hearth Incenerator	1,000's $	Lbs/Hr	1.5	35.525	15312	1	.996	500.18	5	99+
Condenser	$	Gal/Min.	2.5	5.0469E9	5.0398E8	1	.989	266.30	5	99+
Heat Exchanger	$	Area in sqft	1.5	1863624	13446	1	.994	415.24	5	99+
Re Boiler	$	Area in sqft	1.5	2923281	21091	1	.994	415.24	5	99+
Oil Water Separater Concrete Pit	$	CBS.	1.5	50035	384.36	1	.982	41.10	3	90+

*All $ are in mid '78.

†Note: "E9" means 10^9, etc.

General equation form is: $Y^L = \alpha + \beta X^M$.

TABLE D-2. RELEVANT RANGES FOR CURVEFITTING RESULTS

Title	Y-units	Y Range From	Y Range To	X-units	X Range From	X Range To
Tank - Stainless Steel	$	291	1,411	Gal	47.43	503
Ultra Filtration	$	68,000	455,000	Flow in GPM	100	1,000
Air Flotation	1,000's $	45.5	109	Sq. Ft	50	400
Reverse Osmosis	$	20,000	365,000	Gal/day	10,000	500,000
Aerators, CFSS&TFNI	$	4,148	13,387	H.P.	10	75
Steel Buildings	1,000's $	19	69	1,000's sq.ft	4	20
Aerators, SS	$	5,034	14,645	H.P.	10	75
Serfilco Pressurized Tank	$	5,940	13,301	Gal	35	226
Vib. Feeders	$	267	1,256	Ton Sand/hr	2	25
Glass R, Vessel W/O Mixer	$	14,000	40,500	Gal	300	4,000
Glass R, Vessel W. Mixer	$	22,000	60,000	Gal	300	4,000
Comp. Flacq. Clarifier	1,000's $	36.8	108.8	Diameter in ft	30	100
RD Vacuume Filter	1,000's $	86.5	196.0	Sq. Ft Filter area	60	575
Rotory Distributor (Trickling filter)	1,000's $	14.5	52.7	Tank Dia. in ft	25	200
Gas Holder Digester Cover	1,000's $	20,893	115.158	Dia. in ft	30	80
Air Flotation (w/o Tank)	1,000's $	100	136	Sq. ft	600	1,200
Spray Film Evaporator	1,000's $	284	2,651	Gal/Min.	50	2,000
Check Valve	$	190.4	2,784	Inches Dia.	2	14
De Aerator (# 1)	Land Am. in ft^2	26	180.3	Gal/Min.	28.7	805.1
De Aerator (# 2)	Steam in 1,000's lbs/hr	7	280	Gal/Min.	28.7	805.1
De Aerator (# 3)	$	7,339	31,165	Gal/Min.	28.7	805.1

(Continued)

TABLE D-2 (Continued)

Title	Y-units	Y Range From	Y Range To	X-units	X Range From	X Range To
Rotary Kiln Incinerator	$	31,888	212,587	Lbs/Hr	300	5,000
Multiple Hearth Incinerator	1,000's $	1,481	8,185	Lbs/Hr	700	20,000
Condenser	$	14,704	43,403	Gal/Min.	60	800
Heat Exchanger	$	35,431	212,587	Area in Sq.ft	200	7,000
Reboiler	$	47,832	286,992	Area in Sq.ft	200	7,000
Oil Water Separator Concrete Pit	$	4,900	13,900	CBS	950	4,200

APPENDIX E

MODULE DESCRIPTIONS

Module	Description	Technologies Where Used	Lifetime (Years)
Flocculator	Horizontal type with paddle mixers. Each paddle cell is 3600 ft^3 in volume and has a mean retention time of 15 min.	Precipitation/flocculation/sedimentation	10
Flash mixer	Basin where one or more chemicals are combined with the wastestream under highly agitated conditions. Primary structures and equipment include a concrete basin and mixer drive. Maximum volume for a single unit is 96 ft^3. Larger volume demands are met by multiple units.	Precipitation/flocculation/sedimentation	10
Jacketed flash mixer	Same purpose as a flash mixer, except a jacketed reaction vessel instead of a concrete basin is used to accommodate exothermic reactions.	Oxidation/reduction, hydrolysis	5
Aerated lagoon	Excavated and lined earth basin with floating aerators	Aerated lagoon	15
Aerated basin	Concrete basin (10 ft. deep) with surface aerators. Waste is fed in along the center line and effluent wires are located along two sides.	Flotation, activated sludge	10
Sludge digestor	Includes heat exchanger and gas recovery system. Cylindrical tank with sidewall depth of 20 ft. Diameter ranges between 20 and 115 ft. Sludge mixer is also included.	Anaerobic digestion (sludge)	10
Trickling filter	Aerobic biological treatment process. Consists of circular concrete tank holding a bed of plastic media or rocks. Waste is sprayed through the air for aeration and then	Trickling filter	15

(Continued)

Module	Description	Technologies Where Used	Lifetime (Years)
	passed through the bed where the biological film fixed to the media decomposes the organic compounds.		
Waste stabilization pond	Large shallow basin where organic compounds are retained and degraded under both aerobic and anaerobic conditions. The structure consists of ecavated soil basins with soil or concrete linked dikes. Liners are also provided to prevent leaching.	Waste stabilization pond	5
Chemical fixation	A two-part, inorganic chemical system that reacts with all polyvalent metal ions and with certain other waste components. Also reacts with itself to form a chemically and mechanically stable solid for landfilling. The system is based on reactions between soluble silicates and silicate setting agents to produce a solid matrix for binding the inorganic contaminant.	Land disposal	N.A.
Incinerator	Rotary kiln incinerator. Includes afterburner and scrubber.	Incineration	5
Sedimentation basin	Rectangular basin where solid particles in the wastestream are removed from suspension through gravity settling. Clarified waste flows over a weir and out of the basin. Concentrated solids are removed (wasted) from the	Precipitation/ flocculation/sedimentation, aerated lagoon, trickling filter, activated sludge	10

(Continued)

Module	Description	Technologies Where Used	Lifetime (Years)
	basin through a sludge discharge line (sludge underflow).		
Clarifier	Circular basin where solid particles are removed from waste suspensions through gravity settline. The unit is designed to include coagulation and flocculation in certain zones. There is, therefore, optional chemical feed.	Aerated lagoon, trickling filter, activated sludge	10
Rotary drum vacuum filter	Used for dewatering process sludges by drawing the water (filtrate) through the filter media which retains the solid fraction (filter cake). The module includes the vacuum pump, sludge conditioning equipment, and all other necessary components.	Precipitation/ flocculation/sedi-mentation filtration, flotation, trickling filter, anaerobic digestion, activated sludge	5
Air flotation	Solid components are removed by flotation rather than by gravity settling. Energy is added to the system in the form of bubbles, which adhere to the suspended solids. The solids then rise and agglomerate at the surface where they are removed by a skimmer.	Air flotation	10
Oil/water separator	Accomplishes gravity separation of two liquid phases having different densities. This module involves coalescing separation -- a process where plates, inserted in the rise path of oil droplets, tend to coalesce the droplets into larger masses that rise faster.	Oil/water separation	10
Multimedia filter	Accomplishes the separation of suspended matter from the wastestream by passing it through a porous material.	Filtration	10

(Continued)

Module	Description	Technologies Where Used	Lifetime (Years)
	Pressure filters have media contained in a steel tank. Waste is pumped through the filter under pressure, and the media are washed by reversing flow through the filter bed (backwashing). The multimedia filter in beds functions on similar principals under gravity flow.		
Distillation	Distillation is a technique for separating reusable components from a feed stream. The module consists of a distillation tower, reboiler, condenser, and other ancillary components. Steam generation is accomplished by a separate module.	Distillation	5
Evaporator	Used for recovery of concentrated solvents or volatile organic compounds. Heat is provided by condensation of steam on metal tubes inside a chamber of the evaporator. The wastes flowing inside the tubes are heated and the volatile components are drawn off as a vapor. The process differs from distillation in that the vapor is usually a single component or unseparated mixture. Module includes condenser and external separator.	Evaporator	5
Reverse osmosis	Cylindrical vessels containing cartridges composed of bundles of fine hollow fibers or spirally wound membrane sheets. Dilute wastestreams containing metals or other low-molecular weight substances and low suspended solids are applied to the fibers or membranes under high pressure. The	Reverse osmosis	7

(Continued)

Module	Description	Technologies Where Used	Lifetime (Years)
	effluent product may be either very pure water or a high concentration of a desired chemical product.		
Ultra-filtration	UF modules resemble those used in reverse osmosis except that the range of pore size in the former (0.02 to 0.04 mn) limits the ultrafiltration application to that of removal of finely emulsified oils, or other high-molecular weight chemicals and fine suspended solids. Operating pressure is in the range of 10 to 100 psig, compared with the 500 to 1500 psig typical of reverse osmosis. Backflushing is readily accomplished to maintain adequate flow rate.	Ultrafiltration	7
Carbon adsorption	The carbon adsorption module includes the contactor columns, carbon storage, carbon charging system, carbon generation (multiple earth furnace including afterburner and scrubber).	Carbon adsorption	7
Decanter	Decantation is frequently employed for separating precipitated solids from liquids or for density separation of liquid mixtures. The unit consists of a tank which provides sufficient retention time for separation. The separated materials are continuously drawn off at different levels in the tank.	Hydrolysis	10
Chemical storage: gas	Pressure vessels housed in a building contain gases used in oxidation or reduction reactions. Gases are metered into the wastestream using a chlorinator.	Oxidation/reduction	15

(Continued)

Module	Description	Technologies Where Used	Lifetime (Years)
Chemical storage: liquid	Storage for any liquids required during waste treatment. Appropriate liquids are stored in a flat bottom cone top steel tank (AWWA D1-0-76, API 620, or API 650 depending on contents). Other liquids are stored in pressurized vessels (ammonia) or in fiberglass tanks (caustic mixtures).	All technologies	15
Chemical storage: solid	Storage of granular or powdered chemicals for use in waste treatment. Components include a dry chemical storage hopper vibratory, feeder, slaking tank, and metereo feed.	Precipitation/ flocculation/sedimentation, oxidation/reduction	15
Sludge equalization	A tank that serves as a flow equalizer and serves as a site for sludge blending. It can serve as a buffer zone between the highly sensitive anaerobic digestion process and can prevent shock loading of toxic substances. It also is a unit process where chemicals may be added to precipitate heavy metals or buffer acid pH.	Anaerobic/digestion	10
Hazardous waste land disposal site	A land disposal site approved for acceptance of liquid and solid hazardous wastes. The main disposal technique is waste burial, with solid debris deposited in trenches and covered with soil. Leachate monitoring systems are included in this module. Evaporation of liquid wastes in shallow basins is conducted in a separate module (see evaporation pond).	Land disposal	20

(Continued)

Module	Description	Technologies Where Used	Lifetime (Years)
Encapsulation	A process whereby waste solids are dewatered, fixed in a resin, compacted, consolidated (by heat) into a block, and jacketed in a final sealing resin. Disposal in an approved site is still required after the wastes are encapsulated.	Encapsulation	7
Deaerator	The deaerator removes dissolved oxygen from wastes so that corrosion of modular components or piping is minimized. The waste is sprayed into a steam-filled chamber and its temperature is brought within 2 or 3 degrees of that of the stream, at which time most of the dissolved gases are released. Collected and again atomized, the water is impinged by high-velocity steam heated to full steam saturation temperature. The essentially gas-free water is then condensed and stored below baffles in a main retaining tank.	Hydrolysis	5
Evaporation pond	The solar evaporator is a large, shallow lagoon used for reducing the volume of dilute, oil-free aqueous wastes. Often, the evaporation pond is actually a disposal process in that residual salts and other solids are left in the lagoon. In some operations, such sludges are periodically removed. Effective performance requires that the climate be relatively dry. The annual evaporation rate should exceed the annual precipitation.	Evaporation pond	20

(Continued)

Module	Description	Technologies Where Used	Lifetime (Years)
Steam generator	Converts feed water and high pressure return condensate into high pressure steam for use in modules requiring steam as a heat source.	Evaporator, distillation carbon adsorption	7
Building	This optional module may be used for housing equipment (storage) to provide office space for plant personnel and laboratory facilities for waste testing and process monitoring.	As specified	15
Transport	Delivery of solid or liquid wastes between processing sites or to disposal. Transport options: truck or rail.	As specified	N.A.
Yard piping	Piping and valves for conducting wastestreams and sludges between the various modules.	All technologies	15
Pumps	Three types of pumps are included as options: aqueous waste pumps, sludge pumps, and chemical feed pumps.	All technologies	10

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APPENDIX F

SYSTEM VARIABLE EQUATIONS

FLOCCULATOR MODULE

System Variables

```
NCELLS=RNDUP(QINF/1795.2)    ; Number of Cells in Module
NPADS=RNDUP(NCELLS/4.)    ; Number of Paddles in Module

LANDAM = NCELLS*280.56+NPADS*31.22    ; Land Area
LANDAR - LANDAM+24.*SQRT(LANDAM)+144.  ; Land Area Including Buffer

HRSYR = DAYS*HRS    ; Hours of Operation Per Year

TSS=TSS
```

Performance

```
CFCM(CLR1 )=COST(CLR1 ,CAPCF,LANDAR,IRCODE)
CFCM(GRADE)=COST(GRADE,CAPCF,LANDAR,IRCODE)

CM(1)=(CFCM(CLR1 )+CFCM(GRADE)

CFCM(CLAB2)=COST(CLAB2,CAPCF,LANDAR/27.,IRCODE)
CFCM(WALL2)=COST(WALL1,CAPCF,(NCELLS*420.66+NPADS*94.96)/27.,
1 IRCODE)

CM(2)=CFCM(SLAB2)+CFCM(WALL1)

CFCM(FLOCP)=COST(FLOCP,CAPCF,NCELLS,IRCODE)
CFCM(MOTOR)=COST(MOTOR,CAPCF,NCELLS,IRCODE)

CM(3)=CFCM(FLOCP)+CFCM(MOTOR)

CM(4)=0.    ;Not applicable

CFCM(LAND)=COST(LAND,CAPCF,LANDAR,IRCODE)
```

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```
CM(5)=CFCM(LAND)

CM96)=0.

CFOM(OPER1)=COST(OPER 1,OMMCF,MSTAFF*HRSYR*0.002,IRCODE)
CFOM(OPER2)=COST(OPER 2,OMMCF,MSTAFF*HRSYR*0.001,IRCODE)

CFOM(LABOR)=COST(LABOR,OMMCF,MSTAFF*HRSYR*0.042,IRCODE)

OMM(1)=CFOM(OPER1)+CFOM(OPER2)+CFOM(LABOR)

CFOM(POWER)=COST(POWER,OMMCF,17.9*HRSYR,IRCODE)

OMM(2)=CFOM(POWER)

OMM(3)=0.05*CM(3)

OMM(4)=0.    ;None

OMM(8)=    ;Not Applicable
```

Module Specific Parameters, Parameter Definitions

```
        -HRSYR        Hours Operation Per Year
Integer-I,            Misc. Counter
Integer-J,            Misc. Counter
Real    -LANDAM       Module Land Area (Ft*Ft)
        -LANDAR       Total Module Land Area With Buffer(Ft*Ft)
        -NCELLS       Number of Cells
        -NPADS        Number of Paddles
        -QINF         Working Flow (Gal/Min)
        -QINFL        I/O Flow (Gal/Min)
        -TSS          Total Suspended Solids
```

FLASH MIXER MODULE

System Variables

```
NMIX=RUNDUP(QINF/700.)
RATIO=100./(100.-EFF)
DETENT=NMIX/KRATE)*(RATIO**(1./NMIX)-1.)
VOL=(QINF/7.48)*DETENT/NMIX
SURFAR=VOL**0.667)*NMIX
LANDAM=SURFAR+0.33*VOL**0.33+2.778)*NMIX
SQDAM=SQRT(LANDAM)
LANDAR=(SQDAM+6.)*(SQDAM+6.)
HRSYR=DAYS*HRS
```

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EFF is user defined. Default value is 90 percent and no attributes are modified. See description of MODSP Parameters.

KRATE is user defined. A default value of 1 is used. See description of MODSP Parameters.

Quantities of chemicals demanded are user defined. See description of MODSP Parameters and demand streams.

Performance

```
CFCM(CLR1 )=COST(CLR2 ,CAPCF,LANDAR,IRCODE)
CFCM(GRADE)=COST(GRADE,CAPCF,LANDAR,IRCODE_

CM(1)=CFCM(CLR1 )+CFCM(GRADE)

CFCM(SLAB1)=COST(SLAB1,CAPCF,LANDAM/27.,IRCODE)
CFCM(WALLS)=COST(WALLS,CAPCF,(LANDAM-SURFAR)*(VOL**.33)/17.,
1  IRCODE)

CN(2)=CFCM(SLAB1)+CFCM(WALL5)

CFCM(COAG )=COST(COAG , CAPCF,VOL**0.33,IRCODE)

CM(3)=CFCM(COAG )

CM(4)=0,1*CM(3)
CFCM(LAND)=COST(LAND,CAPCF,LANDAR,IRCODE)

CM(5)=CFCM(LAND)

NOT APPLICABLE
```

Module Specific Parameters, Parameter Definitions

02	EFF	Reaction Efficiency (Per cent)
03	KRATE	Reaction Rate (Moles/(Litre*Sec))
04	QAL	Quantity of AL (2) O(3) Needed for Module (GPM)
05	QFE	Quantity of FE CL(3) Needed for Module (GPM)
06	QCA	Quantity of C A O CL Needed for Module (GPM)
07	QPHOS	Quantity of Phosphoric Acid Needed for Module (GPM)
08	QALS	Quantity of AL S O (3) Needed for Module (GPM)
09	QCAO	Quantity of C A O Needed for Module (GPM)
10	QCAHY	Quantity of Calcium Hyrdoxide Needed for Module (GPM)
11	QPOLY	Quantity of Polymer Needed for Module (GPM)
12	QGAS	Quantity of Gases Needed for Module (GPM)

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	-DETENT	Detention Time
	-HRSYR	Hours operation per year
Integer	-I	Misc Counter
Integer	-J	Misc Counter
	-LANDAM	Module Land Area (Ft*Ft)
	-LANDAR	Module Land Area with Buffer (Ft*Ft)
	-NMIX	Number of Mixers
	-QINF	Working Flow (Gal/Min)
	-QINFL	I/O Flow (Gal/Min)
	-RATIO	Efficiency Ratio (Ref 106)
	-SURFAR	Surface Area
	-VOL	Volume

JACKETED FLASH MIXER MODULE

System Variables

```
RATIO= 100./(100.-EFF)
DETENT=1./FRATE*(RATIO-1.)
VOL=QINF*DETENT
DIA=4.375*ALOG(VOL)-7.4
DIAAG=160.*ALOG(VOL)-1.16
LANDAM=0.785*DIA**2.
LANDAR=LANDAM+23.*SQRT(LANDAM)+144.
CONST=1.E-4/(.1413*RTEMP+2.)
HORSP=163.6*VOL*CONST
HRSYR-DAYS*HRS
HOUS=0.
IF(BLDG.EQ.2.) HOUS=1
SITE=1.-HOUS
```

EFF is user defined. Default value is 90 and no attributes are modified. See description of MODSP Parameters.

Quantities of chemicals demanded are user defined. See description of MODSP Parameters and demand streams.

Performance

```
CFCM(CLR1 )=COST(CLR1 , CAPCF,LANDAM*HOUS+LANDAR*SITE,IRCODE)
CFCM(GRADE)=COST(GRADE,CAPCF,LANDAM*HOUS+LANDAR+SIDE,IRCODE)

CM(1)=CFCM(CLR1 )+CFCM(GRADE)

CFCM(SLAB2)-COST(SLAB2,CAPCF,LANDAM/27.,IRCODE)
CFCM(SLAB1)=COST(SLAB1,CAPCF,HOUS*LANDAM/27.,IRCODE)
CFCM(BUILD)=COST(BUILD,CAPCF,HOUS*LANDAR,IRCODE)
```

```
CM(2)+CFCM(SLAB2)+CFCM(SLAB1)+CFCM(BUILD)
CFCM(VESS2(=COST(VESS2,CAPCF,VOL,IRCODE)
CFCM(MOTOR)=COST(MOTOR,CAPCF,HORSP,IRCODE)

CM(3)=CFCM(VESS2+CFCM(MOTOR)

CM(4)=0.1*CFCM(MOTOR)

 CFCM(LAND)=COST(LAND,CAPCF,LANDAR,IRCODE)

 CM(5)=CFCM(LAND)

 Not applicable

 CFOM(OPER1)=COST(OPER1,OMMCF,MSTAFF*HRSYR* .003,IRCODE)
 CFOM(OPER2)=COST(OPER2,OMMCF,MSTAFF*HRSYR* .002,IRCODE)
 CFOM(LABOR)=COST(LABOR,OMMCF,MSTAFF*HRSYR* .098,IRCODE)

 OMM(1)=CFOM(OPER1)+CFOM(OPER2)+CFOM(LABOR)

 CFOM(POWER)=COST(POSER,OMMCF.8.218E-3*QINF*HRSYR,IRCODE)

 OMM(2)-CFOM(POWER)

 OMM(3)=0.05*CM(3)

 Not applicable; costed in storage module

 OMM(4)=0

 Not applicable

 OMM(8)=0
```

Module Specific Parameters, Parameter Definitions

02	EFF	Reaction Efficiency (per cent)
03	KRATE	Reaction Rate (Moles/(Litre*Sec))
04	RTEMP	Reactor Temperature (Deg C)
05	BLDG	Building Flag
06	QAL	Quantity of AL (2) O(3) Needed for Module (GPM)
07	QFE	Quantity of FE CL (3) Needed for Module (GPM)
08	QCA	Quantity of C A O CL Needed for Module (GPM)
09	QPHOS	Quantity of Phosphoric Acid Needed for Module (GPM)
10	QALS	Quantity of AL S O (3) Needed for Module (GPM)
11	QCAO	Quantity of C A O Needed for Module (GPM)
12	QCAHY	Quantity of Calcium Hydroxide Needed for Module (GPM)
13	QPOLY	Quantity of Polymer Needed for Module (GPM)

```
            -LANDAM     Module Land Area (Ft*Ft)
            -LANDAR     Module Land Area with Buffer (Ft*Ft)
            -QINF       Working Flow (Gal/Min)
            -QINFL      I/O Flow (Gal/Min)
            -RATIO      Efficiency Ratio (See Ref 106)
            -SITE       Counter
            -VOL        Volume

            -CONST      Correction Factor for HP
            -DETENT     Detention Time
            -DIA        Diameter of Mixer
            -DIAAG      Diameter of Agitator
            -HORSP      Horse Power Required by Agitator
            -HRSYR      Hours operation per year
      Integer -I        Misc.Counter
      Integer -J        Misc.Counter
```

AERATED LAGOON MODULE

System Variables

```
      CEFL=CINF*(100.-EFF)*0.01
      SURFAR=16.*QINF*CINF-CEFL)/(KRATE*CEFL)
      SQSUR=SQRT(FURFAR)
      LANDAR=(SQSUR+132.)*(SQSUR_132.)
      VOLEX=87.6* SQSUR
      NOAER=RNDUP(2.41E-4*SURFAR)
      HRSYR=DAYS*HRS
      HORSP=((SURFAR*12.)/1000.)*.5
      KWH=HORSP*.7457
```

EFF is user defined. A default value of 90 percent removal is in the program. Note that the varying degradability of hazardous compounds is taken into account by specifying 'KRATE'. See the descriptions under MODSP Parameters.

```
      IFF (CINF/TOTN.GT.20.)
           QAM=(CINF/TOTN-20.)*QINF*2.13E-5
      ELSE
           QAM=UNDEF
      ENDIFF

      IFF (CINF/TOTP.GT.100.)
           QPHOS=(CINF/TOTP-100.)*QINF*2.47E-5
      ELSE
           QPHOS=UNDEF
      ENDIFF

      TOTN=0.
      TOTP=0.
```

Performance

```
CFCM(CLR2 )=COST(CLR2 ,CAPCF,LANDAR,IRCODE)
CFCM(EXCV3)=COST(EXCV3,CAPCF,VOLEX,IRCODE)
CFCM(GRADE)=COST(GRADE,CAPCF,LANDAR,IRCODE)

CM(1)=CFCM(CLR2 )+CFCM(EXCV3)+(GRADE)

CFCM(WALL6)=COST(WALL6,CAPCF,5.5,IRCODE)
CFCM(SLAB1)=COST(SLAB1,CAPCF,3.1,IRCODE)
CFCM(WALL5)=COST(WALL5,CAPCF,1.8,IRCODE)
CFCM(SLAB2)=COST(SLAB2,CAPCF,0.5,IRCODE)
CFCM(WDBM2)=COST(WDBM2,CAPCF,25.,IRCODE)
CFCM(WDBM2)=COST(WDBM1,CAPCF,600.,IRCODE)
CFCM(WDDK )=COST(WDDK ,CAPCF,400.,IRCODE)

CM(2)=CFCM(WALL6)+CFCM(SLAB1)+CFCM(WALL5)+CFCM(SLAB2)+
      CFCM(WDBM2)+CFCM(WDBM1)+CFCM(WDDK)

CFCM(AER50)=COST(AER50,CAPCF,NOAER,IRCODE)
CFCM(GATE )=COST(GATE ,CAPCF,4., IRCODE)

CM(3)=CFCM(AER50)+CFCM(GATE )

Included in Aerator Costs

CFCM(LAND)=COST(LAND,CAPCF,LANDAR,IRCODE)

CM(5)=CFCM(LAND)

CFCM(LINER)=COST(LINER, CAPCF,SURFAR,IRCODE)
CFCM(HNDRL)=COST(HNDRL, CAPCF,104.,IRCODE)
CM(6)=CFCM(LINER)+CFCM(HNDRL)

CFOM(OPER1)=COST(OPER1,OMMCF,MSTAFF*HRSYR* .06 ,IRCODE)
CFOM(OPER2)=COST(OPER2,OMMCF,MSTAFF*HRSYR* .012,IRCODE)
CFOM(LABOR)=COST(LABOR,OMMCF,MSTAFF*HRSYR* .66 ,IRCODE)

OMM(1)=CFOM(OPER1)+CFOM(OPER2)+CFOM(LABOR)

CFOM(POWER)=COST(POSER,OMMCF,KWH*HRSYR,IRCODE)

OMM(20=CFOM(POWER)

OMM(3)=0.05*CM(3)

Not applicable

OMM(8)=0
```

Module Specific Parameters, Parameter Definitions

02 EFF Efficiency (Per cent)
03 KRATE Reaction Rate (Per day)

	-CEFL	Effluent Bod Concentration
	-CINF	Influent Bod Concentration
	-HRSYR	Hours Operation Per Year
Integer	-I	Misc Counter
Integer	-J	Misc Counter
	-LANDAR	Module Land Area with Buffer (Ft*Ft)
	-NOAER	Number of Surface Aerators
	-QAM	Liquid Ammonia (Demand) (Gal/Min)
	-QINF	Working Flow (Gal/Min)
	-QINFL	I/O Flow (Gal/Min)
	-QPHOS	Phosphoric Acid (Demand) (Gal/Min)
	-SQSUR	Square Root of Surface Area
	-SURFAR	Surface Area
	-TOTN	Total Nitrogen
	-TOTP	Total Phosphorus
	-VOLEX	Volume of Excavation for Lagoon(s)

AERATED BASIN MODULE

System Variables

```
CEFL=CINF*(100.-EFF)*0.01
SURFAR=0.042*QINF*(CINF-CEFL)/(1.+10.*Krate)
SQSUR=SQRT(FURFAR)
LANDAR=(SQSUR+12.)*(SQSUR+12.)
NOAER+RNDUP(2.41E-4*SURFAR)
HRSYR=DAYS*HRS
LBSDY=HRSYR*835E-6
HORSP=((SURFAR*20.)*.001)*.5
KWH=HORSP*0.7457
RATN=CINF*0.05
RATP=CINF*0.01
```

Performance (EFF) is user defined. Default value = 90 percent removal. Note that varying degradability of hazardous compounds is taken into account by specifying "KRATE". See MODSP description.

```
IFF (TOTN.GT.RATN)
     QAM=(RATN-TOTN)*QINF*2.13E-5
     TOTN=0.
ELSE
     QAM=UNDEF
     TOTN=TOTN-RATN
```

```
      ENDIFF
      IFF (TOTP.GT.RATP)
          QPHOS=(RATP-TOTP)*QINF*2.47E-5
          TOTP=0.
      ELSE
          QPHOS=UNDEF
          TOTP=TOTP-RATP
      ENDIFF
```

Performance

```
      CFCM(CLR1 )=COST(CLR1 , CAPCF,LANDAR,IRCODE)
      CFCM(GRADE)=COST(GRADE,CAPCF,LANDAR,IRCODE)
      CFCM(EXCV2)=COST(EXCV2,CAPCF,SURFAR/9,IRCODE)

      CM(1)=CFCM(CLR1 )+CFCM(GRADE)+CFCM(EXCV2)

      CFCM(SLAB1)=COST(SLAB1,CAPCF,((SQSUR+2.)/27.,IRCODE)
      CFCM(WALL6)=COST(WALL6,CAPCF,1.2*SQSUR,IRCODE)

      CM(2)=CFCM(SLAB1)+CFCM(WALL6)

      CFCM(AER50)=COST(AER50,CAPCF,NOAER,IRCODE)
      CFCM(PIPE2)=COST(PIPE2,CAPCF,SQSUR,IRCODE)
      CFCM(WEIR )=COST(WEIR ,CAPCF,SWSUR,IRCODE)

      CM(3)=CFCM(AER50)+CFCM(PIPE2)+CFCM(WEIR )

      INCLUDED IN AERATOR COSTS

      CM(4)=0

      CFCM(LAND)=COST(LAND,CAPCF,LANDAR,IRCODE)

      CM(5)=CFCM(LAND)

      NOT APPLICABLE

      CM(6)=0

      CFOM(OPER1)=COST(OPER1,OMMCF,MSTAFF*HRSYR* .06 ,IRCODE)
      CFOM(OPER2)=COST(OPER2,OMMCF,MSTAFF*HRSYR* .012,IRCODE)
      CFOM(LABOR)=COST(LABOR,OMMCF,MSTAFF*HRSYR* .66 ,IRCODE)

      OMM(1)=CFOM(OPER1)+CFOM(OPER2)+CFOM(LABOR)

      CFOM(POWER)=COST(POWER,OMMCF,KWH*HRSYR,IRCODE)

      OMM(2)=CFOM(POWER)
```

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```
OMM(3)=0.2*CM(3)

NOT APPLICABLE-COSTED IN STORAGE MODULE

OMM(4)=0

NOT APPLICABLE

OMM(8)=0
```

Module Specific Parameters, Parameter Definitions

```
02 EFF   Reaction Efficiency (Per Cent)
03 KRATE Reaction Rate (Per Day)

        -CEFL          Effluent BOD Concentration
        -CINF          Influent BOD  Concentration

       -HRSYR          Hours Operation Per Year
 Integer-I             Misc. Counter
       -LANDAR         Module Land Area With Buffer (Ft*Ft)
       -NOAER          Number of Surface Aerators
       -QAM            Liquid Ammonia (Demand) (Gal/Min)
       -QINF           Working Flow (Gal/Min)
       -QINFL          I/O Flow (Gal/Min)
       -QPHOS          Phosphoric Acid (Demand) (Gal/Min)
       -RATN           Required Nitrogen to BOD Level
       -RATP           Required Phosphorus to BOD Level
       -SQSUR          Square Root of Surface Area
       -SURFAR         Surface Area
       -TOTN           Total Nitrogen
       -TOTP           Total Phosphorus
```

SEDIMENTATION BASIN MODULE

System Variables

```
VOL=QINF*DETENT
DEPTH=10.
A=QINF/HYDRAL
B=VOL/10.
IFF (A. GE. B)
     LANDAM=A
ELSE
     LANDAM=B
ENDIFF
```

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BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

```
      WIDTH=SQRT(LANDAM/5.)
      LENGTH-SQRT(LANDAM*5.)
      IFF (WIDTH. LE. 20.)
           HOPWID=WIDTH
      ELSE
           HOPWID+20.
      ENDIFF
      HOPDEP=0.8*HOPWID-1.
      HOPVOL=(0.33)*(6*HOPWID+4+SQRT(6*HOPWID+4))*HOPDEP
      HOPAR=(HOPWID+10.)*HOPDEP
      HOPN=RNDUP(WIDTH/20.)
      LANDAR=LANDAM+24*SQRT(LANDAM)+144
      WALCY=(2*WIDTH*DEPTH+1*LENGTH*DEPTH+HOPAR)*.03
      WEIRL=1.33*LENGTH+WIDTH-1.
      HRSYR= DAYS*HRS
```

Performance should be defined by user in calculating results of settling test and input as MODSP Parameters. Defaults supplies are:

```
           TSS=30.
           PCTSO=8.
```

If a sludge wasting rate is not defined by user (see MODSP par description) "SLUDG" is defined as a function a influent flow.

```
      IFF (SLUDG.EQ.UNDEF)
          SLUDG=0.1*QINF
      ENDIFF

      QEFF=QINF-SLUDG
```

Performance

```
      CFCM(CLR2 )=COST(CLR2 ,CAPCF,LANDAR,IRCODE)
      CFCM(GRADE)=COST(GRADE,CAPCF,LANDAR,IRCORE)
      CFCM(EXCV1)=COST(EXCV1,CAPCF,HOPVOL/27.,IRCODE)

      CM(1)=CFCM(CLR2 )+CFCM(GRADE)+CFCM(EXCV1)

      CFCM(WALL1)=COST(WALL1,CAPCF,WALCY,IRCODE)
      CFCM(SLAB1)=COST(SLAB1,CAPCF,(LANDAM+4.)/27.,IRCODE)

      CF(2)=CFCM(WALL1)+CFCM(SLAB1)

      CFCM(SLCOL)=COST(SLCOL,CAPCF,HOPN*LENGTH,IRCODE)
      CFCM(PIPE4)=COST(PIPE4,CAPCF,HOPDEP+10.,IRCODE)
      CFCM(WEIR )=COST(WEIR,CAPCF,WEIRL,IRCODE)

      CM(3)=CFCM(SLCOL)+CFCM(PIPE4)+CFCM(WEIR )

      CM(4)=0.01*CFCM(SLCOL)
```

```
CFCM(LAND)=COST(LAND,CAPCF,LANDAR,IRCODE)

CM(5)=CFCM(LAND)

NOT APPLICABLE

CM(6)=0

CFOM (OPER1)=COST(OPER1,OMMCF,MSTAFF*HRSYR* .05 ,IRCODE)
CFOM (OPER2)=COST(OPER2,OMMCF,MSTAFF*HRSYR* .003,IRCODE)
CFOM (LABOR)=COST(LABOR,OMMCF,MSTAFF*HRSYR*0.6  ,IRCODE)

OMM(1)=CFOM(OPER1)+CFOM(OPER2)+CFOM(LABOR)

CFOM(POWER)=COST(POWER,OMMCF,1.4*HRSYR,IRCODE)

OMM(2)=CFOM(POWER)

OMM(3)=0.1*CM(3)

NOT APPLICABLE

OMM(4)=0

NOT APPLICABLE

OMM(8)=0
```

Module Specific Parameters, Parameter Definitions

```
02 DETENT  Detention Time in Minures
03 SLUDG   Sludge Wasting Rate (Lb/Hr)
04 HYDRAL  Hydralic Loading
05 TSS     Output TSS as Estimated from Settling Test
06 PCTSO   Output PCTSO as Estimated from Settling Test

          -DEPTH       Basin Depth
          -HOPAR       Hopper Area
          -HOPDEP      Hopper Depth
          -HOPN        Number of Hoppers
          -HOPVOL      Hopper Volume
          -HOPWID      Hopper Width
          -HRSYR       Hours Operation Per Year
          -I           Misc. Counter
          -J           Misc. Counter
          -LANDAM      Module Land Area (Ft*Ft)
          -LANDAR      Module Land Area with Buffer (Ft*Ft)
          -LENGTH      Module Length (Ft)
          -QEFF        Output Flow (Stream 1) (GPM)
```

-QINF	Working Flow (GPM)
-QINFL	Input Flow (GPM)
-SLUDG	Modsp Par and Output Sludge Wasting Rate
-TSS	Modsp Par and Total Suspended Solids
-VOL	Basin Volume (Gallons)
-WALCY	Walk Volume in Cubic Yards
-WIDTH	Basin Width
-WEIRL	Weir Length

CLARIFIER MODULE

System Variables

```
SURFAR=QINF/HYDRAL
SQSUR=SQRT(SURFAR)
LANDAR=SURFAR+14.18*SQSUR+50.27
LANDAM=SURFAR+10.63*SQSUR+27.27
VOLEX=0.148*SURFAR+1.57*SQSUR+7.45
VCON=0.16*SURFAR+0.034*SURFAR**1.5
VFIL=SURFAR+5.32*SQSUR+7.07
BDECK=8.04*SURFAR**0.483
BDBEAM=0.68*SURFAR**0.978
DIAM=2.*SQRT(SURFAR/PI)
CIRC=PI*DIAM
KWHS=10.53*SURFAR
HRSYR=DAYS*HRS
```

Performance should be defined by user in calculating results of settling test, and input as MODSP Parameters. Defaults supplied are:

```
TSS=30.
PCTSO=8.
```

If a sludge wasting rate is not defined by user (see MODSP Par Description) 'SLUDG' is defined as a function a influent flow.

```
IFF (SLUDG.EQ.UNDEF)
     SLUDG=0.1*QINF
ENDIFF

QEFF = QINF-SLUDG

QSULF=0.123*SURFAR
QCAHY=8.0*SURFAR
QCOAG=0.17*SURFAR
```

Performance

```
CFCM(CLR2 )=COST(CLR1 ,CAPCF,LANDAR,IRCODE)
CFCM(GRADE)=COST(GRADE,CAPCF,LANDAM,IRCODE)
```

```
CFCM(EXCV1)=COST(EXCV1,CAPCF,VOLEX,IRCODE)

CM(1)=CFCM(CLR1 )+CFCM(GRADE)+CFCM(EXCV1)

CFCM(WALL1)=COST(WALL1,CAPCF,VCON,IRCODE)
CFCM(BKFL2)=COST(BKFL2,CAPCF,VFIL,IRCODE)
CFCM(WDBM2)=COST(WDBM2,CAPCF,BDBEAM,IRCODE)
CFCM(WDDK )=COST(WDDK ,CAPCF,BDECK,IRCODE)

CM(2)=CFCM(WALL1)+CFCM(BKFL2)+CFCM(WDBM2)+CFCM(WDDK )

CFCM(SLCOL)=COST(SLCOL,CAPCF,DIAM,IRCODE)
CFCM(CLAR1)=COST(CLAR1,CAPCF,DIAM,IRCODE)
CFCM(PIPE4)=COST(PIPE4,CAPCF,DIAM/2.,IRCODE)
CFCM(WEIR )=COST(WEIR ,CAPCF,CIRC,IRCODE)

CM(3)=CFCM(SLCOL)+CFCM(CLAR1)+CFCM(PIPE4)+CFCM(WEIR )

CM(4)=0.01*CFCM(SLCOL)

CFCM(LAND)=COST(LAND,CAPCF,LANDAR,IRCODE)

CM(5)=CFCM(LAND)

NOT APPLICABLE

CM(6)=0.

CFOM(OPER1)=COST(OPER1,OMMCF,MSTAFF*HRSYR* .05 ,IRCODE)
CFOM(OPER2)=COST(OPER2,OMMCF,MSTAFF*HRSYR* .003,IRCODE)
CFOM(LABOR)=COST(LABOR,OMMCF,MSTAFF*HRSYR*0.6  ,IRCODE)

OMM(1)=CFOM(OPER1)+CFOM(OPER2)+CFOM(LABOR)

CFOM(POWER)=COST(POWER,OMMCF,KWHS*HRSYR,IRCODE)

OMM(2)=CFOM(POWER)

OMM(3)=0.1*CM(3)

CHEMICALS COSTED IN THE STORAGE MODULE(S)

OMM(4)=0.

NOT APPLICABLE

OMM(8)=0
```

Module Specific Parameters, Parameter Definitions

02 DEBUG Local Debug Flag
03 HYRDRAL Hydraulic Loading
04 TSS Output TSS as Estimated from Settling Rate
05 PCTSO Output PCTSO

	-BDBEAM	Board Beams (LF)
	-BDECK	Surface Area of Board Deck (Ft*Ft)
	-CIRC	Clarifier Circumference (Ft)
	-DIAM	Clarifier Diameter (Ft)
	-HRSYR	Hours Operation Per Year
Integer	-I	Misc. Counter
Integer	-J	Misc. Counter
Real	-KWHS	Killowatts/Hr
	-LANDAM	Module Land Area (Ft*Ft)
	-LANDAR	Module Land Area With Buffer (Ft*Ft)
	-PCTSOA	Aqueous Percent Solids Output (Zero)
	-QEFF	Effluent Flow Rate (GPM)
	-QINF	Working Flow (GPM)
	-QINFL	Influgent Flow (GPM)
	-SURFAR	Filter Surface Area
	-VCON	Volume of Concrete (CY)
	-VFIL	Volume of Backfill (CY)
	-VOLEX	Volume of Excavation (CY)

ROTARY DRUM VACUUM MODULE

System Variables

```
NOFILT=RNDUP(SLUDG /115.)
QINFU =SLUDG/NOFILT
SURFAR=QINFU*5.
LANDAM=0.95*SURFAR*NOFILT
LANDAR=2.33*LANDAM
LBSHR=SURFAR*NOFILT
HRSYR=DAYS*HRS
VOL=(1.23E-4*SURFAR**3.+0.13*SURFAR*SURFAR+30.68*SURFAR)
KWHS=(0.003*VOL+7.9E-3*SURFAR)*NOFILT
YIELD=LBSHR
FILTRT=SLUDG-(YIELD/(10.42*60.))
HOUS=0.
IF(BLDG.EQ.2.) HOUS=1
SITE=1.-HOUS
```

Performance: Solids output=QINFS (lbs/hr)=yield QFE and Lime Additions (as GPM and lbs/hr) are user specificed. Otherwise = 0

Performance

```
CFCM(CLR1 )=COST(CLR1 ,CAPCF,LANDAM*HOUS+LANDAR*SITE,IRCODE)
CFCM(GRADE)=COST(GRADE,CAPCF,LANDAM*HOUS+LANDAR*SITE,IRCODE)

CM(1)=CFCM(CLR1 )+CFCM(GRADE)

CFCM(SLAB2)=COST(SLAB2,CAPCF,LANDAM/27.,IRCODE)
CFCM(SLAB1)=COST(SLAB1,CAPCF,HOUS*LANDAM/27.,IRCODE)
CFCM(BUILD)=COST(BUILD,CAPCF,HOUS*LANDAR,IRCODE)

CM(2) =CFCM(SLAB2)+CFCM(SLAB1)+CFCM(BUILD)

CFCM(RDVAC)=COST(RDVAC,CAPCF,SURFAR,IRCODE)*1000.

CM(3)=CFCM(RDVAC)*NOFILT

CM(4)=0.01*CM(3)

CFCM(LAND)=COST(LAND,CAPCF,LANDAR,IRCODE)

CM(5)=CFCM(LAND)

NOT APPLICABLE

CM(6)=0

CFOM(OPER1)=COST(OPER1,OMMCF,MSTAFF*HRSYR* .05 ,IRCODE)
CFOM(OPER2)=COST(OPER2,OMMCF,MSTAFF*HRSYR* .013,IRCODE)
CFOM(LABOR)=COST(LABOR,OMMCF,MSTAFF*HRSYR*0.6  ,IRCODE)

OMM(1)=CFOM(OPER1)+CFOM(OPER2)+CFOM(LABOR)

CFOM(POWER)=COST(POWER,OMMCF,KWHS*HRSYR,IRCODE)

OMM(2)=CFOM(POWER)

CFOM(MECH2)=COST(MECH2,OMMCF,20.*NOFILT,IRCODE)
CFOM(HELPR)=COST(HELPR,OMMCF,20.*NOFILT,IRCODE)

OMM(3)=CFOM(MECH2)+CFOM(HELPR)+0.008*CM(3)

CFOM(CAHY1)=COST(CAHY1,OMMCF,LIME*HRSYR,IRCODE)
CFOM(FECL3)=COST(FECL3,OMMCF,FECL3V*HRSYR,IRCODE)

OMM(4)=CFOM(CAHY1)+CFOM(FECL3)

NOT APPLICABLE

OMM(8)=0.
```

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Module Specific Parameters, Parameter Definitions

03 LIME		Lime Addition Rate (Lbs/Hr)
04 FECL3		Ferric Chloride Addition Rate (GPM)
	-FILTRT	Filtrate Flow Rate
	-HOUS	Counter Set by 'Bldg'
	-HRSYR	Hours Operation Per Year
Integer	-I	Misc. Counter
Integer	-J	Misc. Counter
Real	-KWHS	Kilowatts Per Hour
	-LBSHR	Yeild in Lbs/Hr
	-LANDAM	Module Land Area (Ft*Ft)
	-LANDAR	Module Land Area With Buffer (Ft*Ft)
	-NOFILT	Number of Filter Units
	-QINFL	I/O Flow - Filtrate (GPM)
	-QINFS	I/O Loading Rate - Filter Cake (lbs/hr)
	-QINFU	Flow Per Filter Unit (GPM)
	-SITE	Counter Set by 'BLDG'
	-SLUDG	Influent Sludge Flow Rate (GPM)
	-SURFAR	Total Filter Surface Area
	-VOL	Vacuum Drum Volume
	-YIELD	Filter Cake Produced (lbs/hr)

REVERSE OSMOSIS MODULE

System Variables

```
LANDAR=2.25E-2*QINF**1.76+54.
VCON=4.17E-4*QINF**1.76+1.
KWHS=0.215*QINF
HRSYR=HRS*DAYS

QCA=5.61E-4*QINF
SLUDG =7.21E-3*QINF
QEFF=QINF-SLUDG
```

Performance

```
CFCM(CLR1 )=COST(CLR1 ,CAPCF,LANDAR,IRCODE)
CFCM(GRADE)=COST(GRADE,CAPCF,LANDAR,IRCODE)

CM(1)=CFCM(CLR1 )+CFCM(GRADE)

CFCM(SLAB2)=COST(SLAB2,CAPCF,VCON,IRCODE)
```

BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
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```
CM(2)=CFCM(SLAB2)

CFCM(OSMOS)=COST(OSMOS,CAPCF,QINF,IRCODE)

CM(3)=CFCM(OSMOS)

CM(4)=0.05*CM(3)

CFCM(LAND)=COST(LAND,CAPCF,LANDAR,IRCODE)

CM(5=CFCM(LAND)

CM(6)=0; NOT APPLICABLE

CFOM(OPER1)=COST(OPER1,OMMCF,MSTAFF*HRSYR*0.300,IRCODE)
CFOM(OPER2)=COST(OPER2,OMMCH,MSTAFF*HRSYR*0.075,IRCODE)
CFOM(LABOR)=COST(LABOR,OMMCF,MSTAFF*HRSYR*0.400,IRCODE)

OMM(1)=CFOM(OPER1)+CFOM(OPER2)+CFOM(LABOR)

CFOM(POWER)=COST(POWER,OMMCF,KWHS*HRSYR,IRCODE)

OMM(2)=CFOM(POWER)

CFOM(SUPER)=COST(SUPER,OMMCF,1.44E-4*QINF*HRSYR,IRCODE)
CFOM(MECH1)=COST(MECH1,OMMCF,4.33E-4*QINF*HRSYR,IRCODE)
CFOM(MECH2)=COST(MECH2,OMMCH,8.66E-4*QINF*HRSYR,IRCODE)

OMM(3)=CFOM(SUPER)+CFOM(MECH1)+CFOM(MECH2)+0.05*CM(3)

OMM(4)=367.4*QINF

OMM(8)=0.  NOT APPLICABLE
```

Module Specific Parameters, Parameter Definitions

	-HRSYR	Hours Operation Per Year
Integer	-I	Misc. Counter
Integer	-J	Misc. Counter
Real	-KWHS	Kilowatts/hr
	-LANDAR	Module Land Area with Buffer (Ft*Ft)
	-QCA	I/O Quantity of Calcium Hypochlorite Req
	-QEFF	Working Effluent Flow (GPM)
	-QINF	Working Influent Flow (Gal/Min)
	-Qinfl	I/O Flow (Gal/Min)
	-Sludg	Sludge Wasting Rate (GPM)
	-Vcon	Volume of Concrete (CY)

ULTRAFILTRATION MODULE

System Variables

```
      IFF(QINF.LE.200.)
         LANDAM=21.3*QINF
         VEXC=0.47*QINF
      ELSE

         LANDAM=35.6
         VEXC=0.79*QINF
      ENDIFF
       VCON=VEXC
       LANDAR=1.54*LANDAM
       KWH=0.36*QINF
       HRSYR=HRS*DAYS

      QCA=8.83E-5*QINF
      SLUDG=7.21E-3*QINF
```

Performance

```
      CFCM(CLR1 )=COST(CLR1 ,CAPCF,LANDAR,IRCODE)
      CFCM(GRADE)=COST(GRADE,CAPCF,LANDAM,IRCODE)
      CFCM(EXCV1)=COST(EXCV1,CAPCF,VEXC,IRCODE)

      CM(1)=CFCM(CLR1 )+CFCM(GRADE)+CFCM(EXCV1)

      CFCM(SLAB2)=COST(SLAB2,CAPCF,VCON,IRCODE)

      CM(2)=CFCM(SLAB2)

      CFCM(ULTFL)-COST(ULTFL,CAPCF,QINF,IRCODE)

      CM(3)=CFCM(VLTFL)

      CM(4)=0.05*CM(3)

      CFCM(LAND)=COST(LAND,CAPCK,LANDAR,IRCODE)

      CM(5)=CFCM(LAND)

      CM(6)=0.  NOT APPLICABLE

      CFOM(OPER1)=COST(OPER1,OMMCF,MSTAFF*HRSYR*0.300,IRCODE)
      CFOM(OPER2)=COST(OPER2,OMMCF,MSTAFF*HRSYR*0.075,IRCODE)
      CFOM(LABOR)=COST(LABOR,OMMCF,MSTAFF*HRSYR*0.400,IRCODE)
```

```
      OMM(1)=CFOM(OPER1)+CFOM(OPER2)=CFOM(LABOR)

      CFOM(POWER)=COST(POWER,OMMCF,KWH*HRSYR,IRCODE)

      OMM(2)=CFOM(POWER)

      CFOM(MECH1)=COST(MECH1,OMMCF,100.,IRCODE)

      OMM(3)=CFOM(MECH1)

      OMM(4)=0.  NOT APPLICABLE

      OMM(8)=0.  NOT APPLICABLE
```

Module Specific Parameters, Parameter Definitions

	-HRSYR	Hours Operation Per Year
Integer	-I	Misc. Counter
Integer	-J	Misc. Counter
Real	-KWH	Kilowatts Per Hour
	-LANDAM	Module Land Area (Ft*Ft)
	-LANDAR	Module Land Area with Buffer (Ft*Ft)
	-QCA	Required Calcium Hypochlorite Demand
	-QINF	Working Flow (Gal/Min)
	-QINFL	I/O Flow (Gal/Min)
	-SLUDG	Sludge Wasting Rate (GPM)
	-VCON	Volume of Concrete (CY)
	-VEXC	Volume of Excavation (CY)

CARBON ADSORPTION MODULE

System Variables

```
      XAREA=QINF/HYDRAL
      SXAREA=SQRT(XAREA)
      APIER=3.57E-4 *DENTEN*QINF+(6.63E-4 *DENTEN*HYDRAL+4.22E-5*
     +     DETEN*DETEN*HYDRAL*HYDRAL)*SXAREA
      DFEED=8.711E-2*XAREA**0.417*DETEN**0.512
      DHOLD=9.95E-2*XAREA**0.417* DETEN**0.512
      IF(DFEED.LT.12.) GO TO 01
      M=RNDUP((DFEED/11.)**3)
      DFEED=DFEED/M**0.33
      N=RNDUP((DHOLD/11.)**3)
      DHOLD=DHOLD/M**0.33
    GO TO 02
01  M=1
    N=1
02  CONTINUE
```

```
      ASEC=1.074E-4 *DETEN*QINF+(9.49E04 *DETEN*HYDRAL+1.27E-5*
           DETEN*DETEN*HYRDAL*HYRDAL)*SXAREA
      LANDAR=2.*APIER+3.36*SQRT(APIER*XAREA)+1.28*XAREA)+1.38*XAREA+1.101*DFEED
           **2,223*M+1.437E-3**AREA**1.026*DETEN**1.336+1.098*DHOLD**
           2.184*N+2.104E-2*XAREA**0.712*DETEN**0.926
      VEXC=2.85E-3*DETEN*QINF+(5.31E-3*DETEN*HYDRAL+3.38E-4 *DETEN*
     *     DETEN*HYDRAL*HYDRAL)*
           SXAREA+7.15E-3 * DFEED**2.645*M+1.372E-4*XAREA**0.859
           *DETEN**1.118+5.15E-3 *DHOLD**2,678*N+1.564E-4 *XAREA**0.7
           *DETEN**0.911

      VCONP=7.93E-5*DETEN*QINF+(1.47E-4*DETEN*HYDRAL+9.38E-6*DETEN**2
           *HYDRAL**2.)*SXAREA+8.94E-3 *DFEED**2.645*M+1.615E-5
           *XAREA**1.06*DETEN**1.38+6.92E-3 *DHOLD**2.649*N+1.955E-4
           *AREA**0.7*DETEN**0.911
      VSLAB=6.558E-7 *XAREA**1.25*DETEN**1.627+4.395E-4 *XAREA**0.625*
           DETEN**0.814+7.363E-2
      WSTR=7.66*ASEC*(8.87+SXAREA)+30.18*DFEED**2.192*M+3.0E-2*
           XAREA**0.913*DETEN**1.189+6.47*DHOLD**2.291*N+9.32E-2*XAREA
           **0.735*DETEN**0.957
      WVES=36.06*XAREA+6.04*DETEN*HYDRAL*SXAREA+78.7*DFEED**2.039*
           M+22.81*DHOLD**3*N+1.367E-4 *XAREA**1.376*DETEN**1.791+600.
      LBSHR=3.54E-4 *XAREA**1.25* DETEN**1.627
      NGASV=5.68E-2*XAREA**1.26*DETEN**1.641

      KWHS=0.209*XAREA**0.686*DETEN**0.894-189.
    MECHA=2.22E-5 *QINF**0.83+3.9E-5 *XAREA**0.88*DETEN**1.156+.208
    MECHB=7.42E-5 *QNIF**0.83+5.3E-5 *XAREA**0.88*DETEN**1.156+.284
    HELP=5.19E-5*QINF**.83*4.96E-5*XAREA**88*DETEN**1.156+.265
      FOILV=1.96E-5*XAREA**1.26*DETEN**1.641
           IF (.NOT. (MODE.EQ.1.)) GO TO 9008
                OIL=0
                GAS=1
                GO TO 9009
9008       IF (NOT. (MODE.EQ.2.)) GO TO 9009
                OIL=1
                GAS=0
9009  CONTINUE
           CHARG=(QINF/DETEN)*4.45
           HRSYR=DAYS*HRS

      COD=0.2*COD
      QSTM=5.61E-6*XAREA*1.67*DETEN**2.174+6.632E2
```

Performance

```
      CFCM(CLR1 )=COST(CLR1 ,CAPCF,LANDAR,IRCODE)
      CFCM(GRADE)=COST(GRADE,CAPCF,LANDAR,IRCODE)
      CRCM(EXCV2)=COST(EXCV2,CAPCF,VEXC,IRCODE)

      CM(1)=CFCM(CLR1 )+CFCM(GRADE)+CFCM(EXCV2)
```

```
CFCM(SLAB2)=COST(SLAB2,CAPCF,VCONP,IRCODE)
CFCM(SLAB1)=COST(SLAB1,CAPCF,VSLAB,IRCODE)
CFCM(CSPLT)=COST(CSPLT,CAPCF,WSTR,IRCODE)

CM(2)=CFCM(SLAB2)+CFCM(SLAB1)+CFCM(CSPLT)

CFCM(SSPL2)=COST(SSPL2,CAPCF,WXES,IRCODE)
CFCM(HEART)=COST(HEART,CAPCF,LBSHR,IRCODE)
CFCM(ACCAR)=COST(ACCAR,CARCF,CHARG,IRCODE)

CM(3)=CFCM(SSPL2)+CFCM(HEART)+CFCM(ACCAR)

CM(4)=0.001*CM(3)

CFCM(LAND)=COST(LAND,CAPCF,LANDAR,IRCODE)

CM(5)=CFCM(LAND)

CM(6)=0;  NOT APPLICABLE

CFOM(OPER1)=COST(OPER1,OMMCF,MSTAFF*HRSYR*0.300,IRCODE)
CFOM(OPER2)=COST(OPER2,OMMCY,MSTAFF*HRSYR*0.075,IRCODE)
CFOM(LABOR)=COST(LABOR,OMMCF,MSTAFF*HRSYR*0.400,IRCODE)

OMM(1)=CFOM(OPER1)+CFOM(OPER2)+CFOM(LABOR)

CFOM(NGAS )=COST(NGAS ,OMMCF,NGASV*GAS*HRSYR,IRCODE)
CFOM(POWER)=COST(POWER,OMMCF,KWHS*HRSYR,IRCODE)
CFOM(FUEL )=COST(FUEL ,OMMCF,FOILV*OIL*HRSYR,IRCODE)

OMM(2)=CFOM(NGAS )+CFOM(POWER)+CFOM(FUEL )

CFOM(MECH1)=COST(MECH1,OMMCF,MECHA*HRSYR,IRCODE)
CFOM(MECH2)=COST(MECH2,OMMCF,MECHB*HRSYR,IRCODE)
CFOM(HELPR)=COST(HELPR,OMMCF,HELP*HRSYR,IRCODE)

OMM(3)=CFOM(MECH1)+CFOM(MECH2)+CFOM(HELPR)

CFOM(OACCAR)=COST(OACCAR,OMMCF,LBSHR*HRSYR,IRCODE)

OMM(4)=CFOM(OACCAR) ;  MAKE-UP CARBON

OMM(8)=0;  NOT APPLICABLE
```

Module Specific Parameters, Parameter Definitions

```
02 MODE    GAS (1. ) OR OIL (2. ) FIRED FLAG
03 DETEN   CONTACT TIME (MIN)
04 HYDRAL  HYDRALIC LOADING RATE (GPM/FT*FT))
```

	-APIER	PLATFORM AREA CONCRETE PIER (FT*FT)
	-ASEC	INTERMEDIATE VARIABLE
	-CHARG	CARBON REQ. FOR START UP CHARGE (LBS)
	-COD	I/O CHEMICAL OXYGEN DEMAND (PPM)
	-DFEED	DIA OF FURNACE FEED TANK (FT)
	-DHOLD	DIA OF HOLDUP TANK (FT)
REAL	-FOILV	FUEL/OIL VOLUME (GAL/HR)
	-HELP	HELPER COEFFICIENT
	-HRSYR	HOURS OPERATION PER YEAR
INTEGER	-I	MISC. COUNTER
INTEGER	-J	MISC. COUNTER
REAL	-KWHS	KILOWATT HOURS
	-LANDAR	MODULE LAND AREA (FT*FT)
	-LBSHR	CARBON DEMAND (LBS/HR)
	-M	NUMBER OF FURNACE FEED TANKS
	-MECHA	MECH1 COEFFICIENT
	-MECHB	MECH2 COEFFICIENT
	-N	NUMBER OF HOLD UP TANKS
	-NGASV	NATURAL GAS VOLUME (CF/HR)
	-QINF	WORKING FLOW (GAL/MIN)
	-QINFL	I/O FLOW (GAL/MIN)
	-QSTM	STEAM DEMAND (LBS/HR)
	-VCOMP	VOLUME OF CONCRETE PIERS (CY)
	-VEXC	VOLUME OF EXCAVATION (CY)
	-VSLAB	VOLUME OF CONCRETE SLAB FLOORS (CY)
	-WSTR	WEIGHT OF SUPPORT STEEL (LBS)
	-WVES	WEIGHT OF CONTACTOR (LBS)
	-XAREA	CROSS-SECTIONAL AREA OF CONTACTOR (FT*FT)

LAND DISPOSAL SITE MODULES

System Variables

```
LANDAR=9.75*QINFD+405963.02
SQRTLA=SQRT(LANDAR)
HRSYR=DAYS*HRS

NO EQUATIONS

IFF (MODE EQ. 1)
```

Performance

```
CFCM(CLR1 )=COST(CLR1 ,CAPCF,LANDAR,IRCODE)
CFCM(GRADE)=COST(GRADE,CAPCF,LANDAR,IRCODE)
CFCM(CLEXC)=COST(CLEXC,CAPCF,LANDAR*0. 164,IRCODE)

CM(1)=CFCM(CLR1 )+CFCM(GRADE)+CFCM(CLEXC)
```

```
      CFCM(ROAD1)=COST(ROAD1,CAPCF,SQRTLA+4641.03,IRCODE)
      CFCM(ROAD2)=COST(ROAD2,CAPCF,SQRTLA,IRCODE)
      CFCM(PIPE1)=COST(PIPE1,CAPCF,SQRTLA*3.,IRCODE)
      CFCM(ETHWL)=COST(ETHWL,CAPCF,(SQRTLA-459.)*4.,IRCODE)
      CFCM(DBASN)=COST(DBASN,CAPCF,1.,IRCODE)
      CFCM(FENCE)=COST(FENCE,CAPCF,SQRTLA*4.,IRCODE)

      CM(2)=CFCM(ROAD1)+CFCM(ROAD2)+CFCM(PIPE1)+CFCM(ETHWL)+
     1 CFCM(DBASN)+CFCM(FENCE)

      CFCM(FKLFT)=COST(FKLFT,CAPCF,1.,IRCODE)
      CFCM(FELDR)=COST(FELDR,CAPCF,1.,IRCODE)
      CFCM(TKDZR)=COST(TKDZR,CAPCF,1.,IRCODE)
      CFCM(PUTRK)=COST(PUTRK,CAPCF,1.,IRCODE)
      CFCM(WTRK )=COST(WTRK ,CAPCF,1.,IRCODE)
      CFCM(WTANK)=COST(WTANK,CAPCF,1.,IRCODE)

      CM(3)=CFCM(FKLFT)+CFCM(FELDR)+CFCM(TKDZR)+CFCM(PUTRK)+
     1 CFCM(WTRK)+CFCM(WTANK)

      CFCM(GENER)=COST(GENER,CAPCF,1.,IRCODE)

      CM(4)=CFCM(GENER)

      CFCM(LAND)=COST(LAND,CAPCF,LANDAR,IRCODE)

      CM(5)=CFCM(LAND)

      CFCM(LEACH)=COST(LEACH,CAPCF,SQRTLA-360,IRCODE)
      CFCM(GWMON)=COST(GWMON,CAPCF,3.,IRCODE)
      CFCM(LNRCL)=COST(LNRCL,CAPCF,LANDAR*0.135,IRCODE)

      CM(6)=CFCM(LEACH)+CFCM(GWMON)+CFCM(LNRCL)

      CFOM(OPER1)=COST(OPER1,OMMCF,0.2*HRSYR,IRCODE)
      CFOM(OPER2)=COST(OPER2,OMMCF,1.0*HRSYR,IRCODE)
      CFOM(LABOR)=COST(LABOR,OMMCF,1.0*HRSYR,IRCODE)

      OMM(1)=CFOM(OPER1)+CFOM(OPER2)+CFOM(LABOR)

      CFOM(FUEL)=COST(FUEL,OMMCF,13600.,IRCODE)

      OMM(2)=CFOM(FUEL)

      OMM(3)=0.01*CM(3)

      OMM(4)=0.

      CFOM(DMPWT)=0.

      OMM(8)=0.
```

```
      ELSE

      FOR (I=1,6,1)
        CM(I)=0.
      ENDFOR
      FOR (I=1,4,1)
        OMM(I)=0.
      ENDFOR

      CFOM(DMPWT)=COST(DMPWT,OMMCF,QINFD*8.337,IRCODE); HAZ.  WASTE DISPO

      OMM(8)=CFOM(DMPWT)

      ENDIFF
```

Module Specific Parameters, Parameter Definitions

```
          IF MODE = 1 - PURCHASE AND SELF OPERATE
          IF MODE = 2 - DISPOSAL AS SERVICE CHARGE

               -HRSYR        HOURS OPERATION PER YEAR
     INTEGER -I              MISC. COUNTER
     INTEGER -J              MISC. COUNTER
     REAL    -LANDAM         MODULE LAND AREA (FT*FT)
             -LANDAR         MODULE LAND AREA WITH BUFFER (FT*FT)
             -QINFD          WORKING FLOW (GAL/DAY)
             -QINFL          I/O FLOW (GAL/MIN)
             -QINFS          I/O SOLIDS 'FLOW' (LBS/HR)
             -SQRTLA         SQUARE ROOT OF LAND AREA
```

SLUDGE DIGESTER

System Variables

```
      NODIGE=AINT(QINF/55 )
      SURFAR=193*QINF/NODIGE
      LANDAR=(15.7*SQRT(QINF)+16)**2/NODIGE
      HRSYR=NRS*DAYS

      TVS=0.5*TVS
      TSS=0.7*TSS
```

Performance

```
      CFCM(CLR1 )=COST(CLR1 ,CAPCF,LANDAR,IRCODE)
      CFCM(GRADE)=COST(GRADE,CAPCF,LANDAR,IRCODE)
      CFCM(EXCV2)=COST(EXCV2,CAPCF,SURFAR/10,IRCODE)
```

```
CM(1)=(CFCM(CLR1 )+CFCM (GRADE)+CFCM(EXCV2))*NODIGE

CFCM(SLAB1)=COST(SLAB1,CAPCF,SURFAR*0.15,IRCODE)
CFCM(WALL2) =COST(WALL2,CAPCF,33*SQRI(QINF)+1.8,IRCODE)
CFCM(COVER)=COST(COVER,CAPCF,15.7*SQRI(QINF),IRCODE)*1000

CM(2)=(CFCM(SLAB1)+CFCM(WALL2)+CFCM(COVER))*NODIGE

CFCM(GASCO)=COST(GASCO,CAPCF,NODIGE,IRCODE)

CM(3)=CFCM(GASCO)

CM(4)=0.05*CM3

CFCM(LAND)=COST(LAND,CAPCF,LANDAR,IRCODE)

CM(5)=(CFCM(LAND))*NODIGE

CM(6)=0

CFOM(OPER1)=COST(OPER1,OMMCF,MSTAFF*HRSYR*.095,IRCODE)
CFOM(OPER2)=COST(OPER2,OMMCF,MSTAFF*HRSYR*.025,IRCODE)
CFOM(LABOR)=COST(LABOR,OMMCF,MSTAFF*HRSYR*.675,IRCODE)
OMM(1)=CFOM(OPER1)+CFOM(OPER2)+CFOM(LABOR)
OMM(2)=0
CFOM(SUPER)=COST(SUPER,OMMCF,16,IRCODE)
CFOM(MECH1)=COST(MECH1,OMMCF,32,IRCODE)
CFOM(HELPR)=COST(HELPR,OMMCF,40,IRCODE)

OMM(3)=CFOM(SUPER)+CFOM(MECH1)+CFOM(HELPR)0.1*CM(3)

OMM(8)=0
```

Module Specific Parameters, Parameter Definitions

NODIGE	Number of digesters required
QINF	Influent flow rate
TVS	Total volatile solids (ppm)
TSS	Total suspended solids (ppm)

TRICKLING FILTER

System Variables

```
IF(RECIRC.LE.0)RECIRC=20.0
RECYC=QINF*RECIRC*0.01
```

```
      IF(EFF.LE.0),EFF=90
      CEFL=CINF*(100-EFF)*0.01
      SURFAR=((CINF+RECYC*CEFL)/((HRECYC)*CEFL)-1)**2*QINF/9.5
      LANDAR=(2*SQRT(SURFAR/3.14)+12)**2
      WALL=2.96*SQRT(SURFAR)+2.83
      SLAB=0.3*SURFAR+0.88+SQRT(SURFAR)+2
      DIA=SQRT(SURFAR*4/3.14)
      HRSYR=HRS*DAYS

      IF(CINF/TOTN.GT.20),QAM=(CINF/TOTN-20)*QINF*2.13E-5
      IF(CINF/TOTN.LE.20),QAM=0
      IF(CINF/TOTP.GT.100)QPHOS=(CINF/TOTP-100)*QINF*2.47E-5
      IF(CINF/TOTP.LE.100)QPHOS=0


*     CINF=CEFL
```

Performance

```
      CFCM(CLR1 )=COST(CLR1,CAPCF,LANDAR,IRCODE)
      CFCM(GRADE)=COST(GRADE,CAPCF,LANDAR,IRCODE)
      CFCM(EXCV2)=COST(EXCV2,CAPCF,SURFAR/9,IRCODE)

      CM(1)=CFCM(CLR1 )+CFCM(GRADE)+CFCM(EXCV2)

      CFCM(WALL2)=COST(WALL2,CAPCF,WALL,IRCODE)
      CFCM(SLAB1)=COST(SLAB1,CAPCF,SLAB,IRCODE)

      CM(2)=CFCM(WALL2)+CFCM(SLAB1)

      CFCM(DISTR)=COST(DISTR,CAPCF,DIA,IRCODE)*1000
      CFCM(GATE)=COST(GATE,CAPCF,1,IRCODE)

      CM(3)=CFCM(DISTR)+CFCM(GATE)

      CM(4)=0
      CFCM(LAND)=COST(LAND,CAPCF,LANDAR,IRCODE)

      CM(5)=CFCM(LAND)

      CFCM(MEDIA)=COST(MEDIA,CAPCF,SURFAR*30,IRCODE)

      CM(6)=CFCM(MEDIA)

      CFOM(OPER1)=COST(OPER1,OMMCF,MSTAFF*HRSYR*0.02 ,IRCODE)
      CFOM(OPER2)=COST(OPER2,OMMCF,MSTAFF*HRSYR*0.003,IRCODE)
      CFOM(LABOR)=COST(LABOR,OMMCF,MSTAFF*HRSYR*0.38 ,IRCODE)

      OMM(1)=CFOM(OPER1)+CFOM(OPER2)+CFOM(LABOR)

      OMM(2)=0
```

```
      CFOM(MECH2)=COST(MECH2,OMMCF,16,IRCODE)
      CFOM(SUPER)=COST(SUPER,OMMCF,4 ,IRCODE)
      CFOM(FORMA)=COST(FORMA,OMMCF,4 ,IRCODE)
      CFOM(HELPR)=COST(HELPR,OMMCF,32,IRCODE)

      OMM(3)=CFOM(MECH2)+CFOM(SUPER)+CFOM(FORMA)+CFOM(HELPR)0.1*CM(3)

      OMM(4)=0

      OMM(8)=0
```

Module Specific Parameters, Parameter Definitions

EFF	Percent BOD removal efficiency
CINF	Influent BOD concentration (ppm)
CEFL	Effluent BOD concentration
QINF	Influent flow
RECIRC	Recirculation flow (designated as a percent of the influent flow rate
WALL	Volume of walls in CY
SLAB	Volume of slab in CY
DIA	Diameter of the filter

WASTE STABILIZATION POND

System Variables

```
      SURFAR=1.69*QINF*CINF*(1.085**(35-TEMP)
      SQSUF=SQRT(SURFAR)
      IF(SURFAR.LE.6.534E5),GO TO 01
      IF(SURFAR.GT.6.534E5.AND.SURFAR.LE.1.307E6),GO TO 02
      IF(SURFAR.GT.1.307E6.AND.SURFAR.LE.2.614E6),GO TO 03
      IF(SURFAR.GT.2.614E6),GO TO 04
   01 LANDAR=SURFAR+0.92*SQSUF+9148
      VOLEX=22.68*SQSUF
      GO TO 05
   02 LANDAR=SURFAR+0.74*SQSUF+11761
      VOLEX=34.02*SQSUF
      GO TO 06
```

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```
   03 LANDAR=SURFAR+1.2*SQSUF+15246
      VOLEX=45.36*SQSUF
      GO TO 06
   04 LANDAR=SURFAR+1.3*SQSUF+18295
      VOLEX=56.70*SQSUF
      GO TO 06
   05 SIZE=1
      GO TO 07
   06 SIZE=2
   07 HRSYR=HRS*DAYS


      CINF=0.8*CINF
```

Performance

```
      CFCM(CLR1 )=COST(CLR1 ,CAPCF,LANDAR,IRCODE)
      CFCM(EXCV3)=COST(EXCV3,CAPCF,VOLEX,IRCODE)
      CFCM(GRADE)=COST(GRADE,CAPCF,LANDAR,IRCODE)

      CM(1)=CFCM(CLR1 )+CFCM(EXCV3)+CFCM(GRADE)

      CFCM(SLAB1)=COST(SLAB1,CAPCF,SIZE*2,IRCODE)
      CFCM(WALL5)=COST(WALL5,CAPCF,SIZE*1.5,IRCODE)
      CFCM(WDBM1)=COST(WDBM1,CAPCF,SIZE*160,IRCODE)
      CFCM(WDDK)=COST(WDDK,CAPCF,SIZE8192,IRCODE)

      CM(2)=CFCM(SALB1)+CFCM(WALL5)+CFCM(WDBM1)+CFCM(WDDK)

      CFCM(GATE)=COST(GATE,CAPCF,SIZE*3,IRCODE)

      CM(3)=CFCM(GATE)

      CM(4)=0

      CFCM(LAND)=COST(LAND,CAPCF,LANDAR,IRCODE)

      CM(5)=CFCM(LAND)

      CFCM(LINER)=COST(LINER,CAPCF,SURFAR,IRCODE)
      CFCM(HNDRL)=COST(HNDRL,CAPCF,52,IRCODE)

      CM(6)=CFCM(LINER)+CFCM(HNDRL)

      CFOM(OPER1)=COST(OPER1,OMMCF,MSTAFF*HRSYR* .125,IRCODE)
      CFOM(OPER2)=COST(OPER2,OMMCF,MSTAFF*HRSYR* .065,IRCODE)
      CFOM(LABOR)=COST(LABOR,OMMCF,MSTAFF*HRSYR* .342,IRCODE)

      OMM(1)=CFOM(OPER1)+CFOM(OPER2)+CFOM(LABOR)
```

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EPA-287 (Cin.)
(4-76)

OMM(2)=0

OMM(3)=0.1*(CM_2+CM_3)

OMM(4)=0

OMM(8)=0

Module Specific Parameters, Parameter Definitions

QINF	Influent flow rate (GPM)
CINF	Influent BOD (ppm)
TEMP	Temperature of the influent waste (^{o}C)
SIZE	A Counter
VOLEX	Volume of excavation for lagoons

CHEMICAL FIXATION

System Variables

```
GALYR=QINFL*DAYS*HRS*60
CORECT=1
COREX=0
IFF(PCTSOL.GT.10)
CORECT=0
COREX=1
ENDIFF

QINFS=QINFL*1.79E-4
```

Performance

```
CM(1)=0

CM(2)=0

CM(3)=0

CM(4)=0

CFCM(LAND)=COST(LAND,CAPCF
```

```
CM(5)=0

CM(6)=0

CFOM(OPER1)=COST(OPER1,OMMCF,MSTAFF*HRSYR* .    ,IRCODE)
CFOM(OPER2)=COST(OPER2,OMMCF,MSTAFF*HRSYR* .    ,IRCODE)
CFOM(LABOR)=COST(LABOR,OMMCF,MSTAFF*HRSYR* .    ,IRCODE)

OMM(1)=0

OMM(2)=0

OMM(3)=0

OMM(4)=0
CFOM(CHFX1)=COST(CHFX1,OMMCF,GALYR*CORECT,IRCODE)
CFOM(CHFX2)=COST(CHFX2,OMMCF,GALYR*COREX,IRCODE)

OMM(8)=CFOM(CHFX1)+CFOM(CHFX2)
```

Module Specific Parameters, Parameter Definitions

GALYR	Gallons/yr of waste input
QINFL	Influent flow rate
PCTSOL	Percent solids in influent ($\%wt/_{wt}$)
CORECT	Counter
COREX	Counter

INCINERATOR

System Variables

```
LANDAM=55+0.0674*QINFS**1.074
LANDAR=88+0.108*QINFS**1.074
VOLEX=1.222+0.0015*QINFS**1.074
VSLAB=VOLEX
KWA=6.6*QINFS**0.431
HRSYR=HRS*DAYS
GALYR=QINFL*60*HRSYR
```

Performance

```
CFCM(CLR1 )=COST(CLR1 ,CAPCF,LANDAR,IRCODE)
CFCM(GRADE)=COST(GRADE,CAPCF,LANDAR,IRCODE)
CFCM(EXCV2)=COST(EXCV2,CAPCF,VOLEX,IRCODE)

CM(1)=CFCM(CLR1 )+CFCM(GRADE)+CFCM(EXCV2)

CFCM(SLAB1)=COST(SLAB1,CAPCF,VSLAB,IRCODE)

CM(2)=CFCM(SLAB1)

CFCM(INCIN)=COST(INCIN,CAPCF,QINFS,IRCODE)

CM(3)=CFCM(INCIN)

CM(4)=0.001*CM(3)

CFCM(LAND)=COST(LAND,CAPCF,LANDAR,IRCODE)

CM(5)=CFCM(LAND)

CM(6)=0

CFOM(OPER1)=COST(OPER1,OMMCF,MSTAFF*HRSYR*0.6   ,IRCODE)
CFOM(OPER2)=COST(OPER2,OMMCF,MSTAFF*HRSYR* .225,IRCODE)
CFOM(LABOR)=COST(LABOR,OMMCF,MSTAFF*HRSYR*0.1   ,IRCODE)

OMM(1)=CFOM(OPER1)+CFOM(OPER2)+CFOM(LABOR)

CFOM(POWER)=COST(POWER,OMMCF,KWH*HRSYR,IRCODE)

OMM(2)=CFOM(POWER)

CFOM(MECH1)=COST(MECH1,OMMCF,HRSYR*0.6,IRCODE)

OMM(3)=CFOM(MECH1)+25245+205.4*LBSHR**0.585

OMM(4)=0

CFOM(INCIN)=COST(INCIN,OMMCF,CALYR,IRCODE)

OMM(8)=CFOM(INCIN)
```

Module Specific Parameters, Parameter Definitions

QINFS	Solids loading rate (lbs/hr)
QUNFL	Liquid influent rate GPM

VOLEX	Volume of excavation (CY)
VSLAB	Volume of concrete slab(CY)
GALYR	Gallons of liquid waste per yr
KWH	Kilowatts per hour

AIR FLOTATION

System Variables

```
LANDAM=QINF*TSS  *2.22E-4
LANDAR=LANDAM+12*SQRT(LANDAM)+144
WIDTH=SQRT(LANDAM/2. )
LENGTH=2.*WIDTH
DEPTH=10.
WALL=1.666*DEPTH*(LENGTH+WIDTH)
BLD=0.
NOBLD=1.
IFF(QINF.GT.500.)
    BLD=1.
    NOBLD=0.
ENDIFF
KWHS=(0.1616*LANDAM+5.97)
HRSYR=DAYS*HRS

TSS=TSS*0.014
PCTSO=5.8
SLUDG=0.08*QINF
QPOLY=2.05E-4*LANDAM
```

Performance

```
CFCM(CLR1 )=COST(CLR1 ,CAPCF,LANDAR,IRCODE)
CFCM(GRADE)=COST(GRADE,CAPCF,LANDAM,IRCODE)

CM(1)=CFCM(CLR1 )+CFCM(GRADE)

CFCM(SLAB1)=COST(SLAB1,CAPCF,LANDAR/27.,IRCODE)
CFCM(WALL1)=COST(WALL1,CAPCF,(WALL/27.)*BLD,IRCODE)
CFCM(BUILD)=COST(BUILD,CAPCF,LANDAR*BLD,IRCODE)*1000.

CM(2)=CFCM(SLAB1)+CFCM(WALL1)CFCM(BUILD)

CFCM(AFLTT)=COST(AFLTT,CAPCF,LANDAM*NOBLD,IRCODE)*1000.
CFCM(ARFLT)=COST(ARFLT,CAPCF,LANDAM*BLD,IRCODE)*1000.
CFCM(ACOMP)=COST(ACOMP,CAPCF,BLD,IRCODE)
```

```
CM(3)=CFCM(AFLTT)+CFCM(ARFLT)+CFCM(ACOMP)

CM(4)=0

CFCM(LAND)=COST(LAND,CAPCF,LANDAR,IRCODE)

CM(5)=CFCM(LAND)

CM(6)=0

CFOM(OPER1)=COST(OPER1,OMMCF,MSTAFF*HRSYR* .038,IRCODE)
CFOM(OPER2)=COST(OPER2,OMMCF,MSTAFF*HRSYR* .007,IRCODE)
CFOM(LABOR)=COST(LABOR,OMMCF,MSTAFF*HRSYR*0.8  ,IRCODE)

OMM(1)=CFOM(OPER1)+CFOM(OPER2)+CFOM(LABOR)

CFOM(POWER)=COST(POWER,OMMCF,KWHS*HRSYR,IRCODE)

OMM(2)=CFOM(POWER)

CFOM(MECH1)=COST(MECH1,OMMCF,16.,IRCODE)
CFOM(HELPR)=COST(HELPR,OMMCF,16.,IRCODE)

OMM(3)=CFOM(MECH1)+CFOM(HELPR)+0.05*CM(3)

OMM(4)=0

OMM(8)=0
```

Module Specific Parameters, Parameter Definitions

QINF	Influent flow rate GPM
WIDTH	Width of flotation unit (ft)
LENGTH	Length of flotation unit (ft)
DEPTH	Depth of flotation unit (ft)
WALL	Volume of concrete (ft^3)
BLD	Counter (turns on & off building for smaller (<500 gpm)units
NOBLD	Same as Bldg (set by QINF)
KWHS	Kilowatts/hr
TSS	Influent total suspended solids(ppm)
PCTSO	Percent solids (% wt/wt)

Module Specific Parameters, Parameter Definitions (continued)

SLUDG	Sludge wasting rate (GPM)
QPOLY	Polymer inflow rate (GPM)

OIL/WATER SEPARATOR

System Variables

```
NOSEP=QINF/150.
QINFU=QINF/NODEP
IFF=(TEMP.LE.20.)
EXP1=1301./(998.333+8.1855*(TEMP-20)-1.053E-3*(TEMP-20.)**2.)-3.30233
NUMI=10.**EXP1
VISCOS=NUM1/100.
ELSE
EXP2=(13272.*(20.-TEMP)-1.053E-3*(TEMP-20.)**2.)/TEMP+105.
NUM2=10.**EXP2
VISCOS=NUM2/100.
ENDIFF
VRISE=(1.29E-3*(1.-OILSG)*DROPUM*DROPUM)/VISCOS
TRISE=0.25/VRISE
VPLATE=QINFU*TRISE*0.1337
LANDAM=VPLATE*0.8*NOSEP
LANDAR=(LANDAM+12.*SQRT(LANDAM)+144.)
PLTSTK=(VPLATE/1.9)*NOSEP
WEIGHT=VPLATE*34.*NOSEP
HRSYR=DAYS*HRS
IFF(MODE.EQ.2)
   BLD=1.
   NOBLD=0.
ELSE
   BLD=0.
   NOBLD=1.
ENDIFF
SLUDGE=OIL*QINF*1.11E-6
OIL=15.
QDM USER DEFINED AS GPM DEMULSIFIER REQUIRED. OTHERWISE;

IF(QDM.LT.0),QDM=0
```

Performance

```
CFCM(CLR1 )=COST(CLR1 ,CAPCF,LANDAR,IRCODE)
CFCM(GRADE)=COST(GRADE,CAPCF,LANDAR,IRCODE)

CM(1)=CFCM(CLR1 )+CFCM(GRADE)
```

```
CFCM(SLAB2)=COST(SLAB2,CAPCF,LANDAR/27.,IRCODE)
CFCM(BUILD)=COST(BUILD,CAPCF,LANDAR*BLD,IRCODE)*1000.

CM(2)=CFCM(SLAB2)+CFCM(BUILD)

CFCM(OILWA)=COST(OILWA,CAPCF,WEIGHT,IRCODE)
CFCM(PLATE)=COST(PLATE,CAPCF,PLTSTK,IRCODE)

CM(3)=CFCM(OILWA)+CFCM(PLATE)

CM(4)=0

CFCM(LAND)=COST(LAND,CAPCF,LANDAR,IRCODE)

CM(5)=CFCM(LAND)

CM(6)=0

CFOM(OPER1)=COST(OPER1,OMMCF,MSTAFF*HRSYR*0.038,IRCODE)
CFOM(OPER2)=COST(OPER2,OMMCF,MSTAFF*HRSYR*0.007,IRCODE)
CFOM(LABOR)=COST(LABOR,OMMCF,MSTAFF*HRSYR*0.8   ,IRCODE)

OMM(1)=CFOM(OPER1)+CFOM(OPER2)+CFOM(LABOR)

OMM(2)=0

CFOM(MECH1)=COST(MECH1,OMMCF,16.,IRCODE)
CFOM(HELPR)=COST(HELPR,OMMCF,16.,IRCODE)

OMM(3)=CFOM(MECH1)+CFOM(HELPR)+0.05*CFCM(PLATE)

OMM(4)=0

OMM(8)=0.
```

Module Specific Parameters, Parameter Definitions

NOSEP	Number of separators
QINFU	Flow to an individual unit (GPM)
QINF	Overall influent flow rate
TEMP	Waste temperature (^{o}C)
EXPI NUMI VISCOS EXP 2 NUM 2	) Calculates Viscosity correction factors (see handbook of chemicals)

Module Specific Parameters, Parameter Definitions(continued)

VRISE	Oil droplet rise rate
TRISE	Oil droplet rise rate in a plate
VPLATE	Plate volume
PLTSTK	Height of plates (total)
WEIGHT	Weight of plates (lbs)
BLD	Counters to include/exclude
NOBLD	Building options (set by MODE)
MODE	MODE = 1 excludes building MODE = 2 includes building

MULTI-MEDIA FILTRATION

System Variables

```
SURFAR=QINF/5.
SQSUF=SQRT(SURFAR)
IFF(QINF.LT.5000.)
  LANDAR=0.79*(SURFHR+SQSUF+36.)
  FOUND=0.5*SURFAR
    VOL=41.14*SURFAR
    VOLEX=0.
    WALL=0.
    TROAG=0.
ENDIFF
INF(QINF.GE.5000.)
  LANDAR=SURFAR+27.33*SQSUF+186.78
  FOUND=SURFAR+3.33*SQSUF+2.78
  WALL=5.5*(FOUND-SURFAR)
  VOLEX=LANDAR/9.
    VOL=0.
  TROAG=INT(SQSUF/6+1)*SQSUF
ENDIFF
HRSYR=HRS*DAYS
VOLMED=QINF/540

QWA=0.3*QINF
TSS=0.4*TSS
PCTSO=0.4*PCTSO
SLUDG=QWA
```

Performance

```
CFCM(CLR2 )=COST(CLR2 ,CAPCF,LANDAR,IRCODE)
CFCM(GRADE)=COST(GRADE,CAPCF,SURFAR,IRCODE)
CFCM(EXCV2)=COST(EXCV2,CAPCF,VOLEX,IRCODE)

CM(1)=CFCM(CLR2 )+CFCM(GRADE)+CFCM(EXCV2)

CFCM(SLAB2)=COST(SLAB2,CAPCF,FOUND,IRCODE)
CFCM(WALL1)=COST(WALL1,CAPCF,WALL,IRCODE)
CFCM(VAULT)=COST(VAULT,CAPCF,1.0 ,IRCODE)

CM(2)=CFCM(SLAB2)+CFCM(WALL1)+CFCM(VAULT)

CFCM(PIPE1)=COST(PIPE1,CAPCF,2.5*SQSUF,IRCODE)
CFCM(PRTNK)=COST(PRTNK,CAPCF,VOL,IRCODE)
CFCM(PROUG)=COST(TROUG,CAPCF,TROAG,IRCODE)

CM(3)=CFCM(PIPE1)+CFCM(PRTNK)+CFCM(TROUG)

CM(4)=0; Not applicable

CFCM(LAND)=COST(LAND,CAPCF,LANDAR,IRCODE)

CM(5)=CFCM(LAND)

CFCM(COAL)=COST(COAL,CAPCF,VOLMED*6,IRCODE)
CFCM(SAND)=COST(SAND,CAPCF,VOLMED*4,IRCODE)

CM(6)=CFCM(COAL)+CFCM(SAND)

CFOM(OPER1)=COST(OPER1,OMMCF,MSTAFF*HRSYR*0.010,IRCODE)
CFOM(OPER2)=COST(OPER2,OMMCF,MSTAFF*HRSYR*0.038,IRCODE)
CFOM(LABOR)=COST(LABOR,OMMCF,MSTAFF*HRSYR*0.488,IRCODE)

OMM(1)=CFOM(OPER1)+CFOM(OPER2)+CFOM(LABOR)

OMM(2)=0; (GRAVITY FEED)

CFOM(MECH1)=COST(MECH1,OMMCF,40,IRCODE)
CFOM(HELPR)=COST(HELPR,OMMCF,80,IRCODE)

OMM(3)=CFOM(MECH1)+CFOM(HELPR)+0.1*CM(3)+0.5*CM(6)

OMM(4)=0; Not applicable

OMM(8)=0; Not applicable
```

Module Specific Parameters, Parameter Definitions

QINF	Influent flow rate (GPM)
VOLEX	Volume of excavation (CY)
WALL	Volume of walls (CY)
TROAG	Length of backwash troughs equipped w/agitators(LF)
FOUND	Volume of foundation (CY)
VOLMED	Volume of media (CY)(A common factor multiplied by 6 for coal,and 4 for sand; see cost category CM6)

DISTILLATION

System Variables

```
VAPQEF=QINF*SEPVAP*VAPDEN*2.228E-5
LIQQEF=QINF*(100-SEPVAP)*LIQDEN*2.228E-5
DENRA=LIQDEN/VAPDEN
MFLOR=LIQQEF/VAPQEF
SURFAR=1.945E-3.*QINF*SQRT(DENRA)/((MFLOR+1)*MFLOR**-0.067*DENR
       A**0.0335-1))
LANDAM=1.91*SURFAR
LANDAR=4*LANDAM
  VEXC=0.15*SURFAR
  SQSUF=SQRT(SURFAR)
  NSTR=35.*SURFAR+11.5*SQSUF+34.2
  WCOL=292.*SURFAR
  WTRAY=35.*SURFAR
WLAPL=24.4*SURFAR+203.*SQSUF+600.
  KWH=802.88*QINF
  HRSYR=HRS*DAYS
  QANF=QINF

QSTM=1.08E3*QINF
SLUDG=QINF*(100-SEPVAP)*.01
QINF=QINF*SEPVAP*.01
```

Performance

```
CFCM(CLR1 )=COST(CLR1 ,CAPCF,LANDAR,IRCODE)
CFCM(GRADE)=COST(GRADE,CAPCF,LANDAM,IRCODE)
CFCM(EXCV1)=COST(EXCV1,CAPCF,VEXC,IRCODE)

CM(1)=CFCM(CLR1 )+CFCM(GRADE)+CFCM(EXCV1)
```

```
CFCM(SLAB2)=COST(SLAB2,CAPCF,VCON,IRCODE)
CFCM(STRST)=COST(STRST,CAPCF,WSTR,IRCODE)

CM(2)=CFCM(SLAB2)+CFCM(STRST)

CFCM(SSPL1)=COST(SSPL1,CAPCF,WCOL,IRCODE)
CFCM(CSPLT)=COST(CSPLT,CAPCF,WTRAY,IRCODE)
CFCM(CONDE)=COST(CONDE,CAPCF,QANF,IRCODE)
CFCM(REBO1)=COST(REBO1,CAPCF,QANF**0.67,IRCODE)
CFCM(STRST)=COST(STRST,CAPCF,WLAPL,IRCODE)

CM(3)=CFCM(SSPL1)+CFCM(CSPLT)+CFCM(CONDE)+CFCM(REBO1)+CFCM(STRST)

CM(4)=0.05*CM(3)

CFCM(LAND)=COST(LAND,CAPCF,LANDAR,IRCODE)

CM(5)=CFCM(LAND)

CM(6)=0; Not applicable

CFOM(OPER1)=COST(OPER1,OMMCF,MSTAFF*HRSYR*0.30 ,IRCODE)
CFOM(OPER2)=COST(OPER2,OMMCF,MSTAFF*HRSYR*0.15 ,IRCODE)
CFOM(LABOR)=COST(LABOR,OMMCF,MSTAFF*HRSYR*0.40 ,IRCODE)

OMM(1)=CFOM(OPER1)+CFOM(OPER2)+CFOM(LABOR)

CFOM(POWER)=COST(POWER,OMMCF,KWH*HRSYR,IRCODE)

OMM(2)=CFOM(POWER)

CFOM(MECH1)=COST(MECH1,OMMCF,0.01*QANF*HRSYR,IRCODE)
CFOM(MECH2)=COST(MECH2,OMMCF,0.009*QANF*HRSYR,IRCODE)
CFOM(HELPR)=COST(HELPR,OMMCF,0.002*QANF*HRSYR,IRCODE)

OMM(3)=CFOM(MECH1)+CFOM(MECH2)+CFOM(HELPR)+0.005*CM(3)

OMM(4)=0; Not applicable

OMM(8)=0: not applicable
```

Module Specific Parameters, Parameter Definitions

LIQDEN	Liquid phase density (lb/ft^3)
VAPDEN	Vapor Phase density (lb/ft^3)
LIQQEF	Liquid phase discharge rate (lb/sec)
VAPQEF	Vapor phase discharge rate (lb/sec)

DENRA	Density ratio = liqden/vapden
MFLOR	Liqqef/vapqef = 1/seprat
VEXC	Volume of excavation (CY)
WSTR	Weight of suppt. steel (lbs)

Module Specific Parameters, Parameter Definitions

WCOL	Weight of dist. column (lbs)
WTRAY	Weight of packing trays (lbs)
WLAPL	Weight of ladders and platforms (lbs)
KWH	Kilowatts per hour
SEPVAP	Percent of total discharge flow (GPM) represented by the condensate (expressed as a %)
QSTM	Steam demand, lbs/hr
QINF	Influent flow rate (GPM)
SLUDG	Sludge (heavy fraction) wasting rate

EVAPORATOR

System Variables

```
LANDAM=0.46*QINF
LANDAR=4.0*LANDAM
SURFAR=LANDAR/1.91
  VEXC=0.15*SURFAR
  VCON=0.17*SURFAR
SQSUF=SQRT(SURFAR)
  WSTR=35.*SURFAR+11.5*SQSUF+34.2
WLAPL=24.4*SURFAR+203*SQSUF+600
  KWH=802.88*QINF
  HRSYR=HRS*DAYS
  QANF=QINF

QSTM=40*QINF
SLUDG=QINF*(100-SEPVAP)*0.01
QINF=QINF*SEPVAP*0.01
```

Performance

```
CFCM(CLR1 )=COST(CLR1 ,CAPCF,LANDAR,IRCODE)
CFCM(GRADE)=COST(GRADE,CAPCF,LANDAM,IRCODE)
CFCM(EXCV1)=COST(EXCV1,CAPCF,VEXC,IRCODE)

CM(1)=CFCM(CLR1 )+CFCM(GRADE)+CFCM(EXCV1)

CFCM(SLAB2)=COST(SLAB2,CAPCF,VCON,IRCODE)
CFCM(STRST)=COST(STRST,CAPCF,WSTR,IRCODE)

CM(2)=CFCM(SLAB2)+CFCM(STRST)

CFCM(EVAP)=COST(EVAP ,CAPCF,QANF*1000,IRCODE)
CFCM(CONDE)=COST(CONDE,CAPCF,QANF,IRCODE)
CFCM(STRST)=COST(STRST,CAPCF,WLAPL,IRCODE)

CM(3)=CFCM(EVAP)+CFCM(CONDE)+CFCM(STRST)

CM(4)=0.05*CM(3)

CM(5)=CFCM(LAND)
CM(6)=0; Not applicable

CFOM(OPER1)=COST(OPER1,OMMCF,MSTAFF*HRSYR*0.30 ,IRCODE)
CFOM(OPER2)=COST(OPER2,OMMCF,MSTAFF*HRSYR*0.15 ,IRCODE)
CFOM(LABOR)=COST(LABOR,OMMCF,MSTAFF*HRSYR*0.40 ,IRCODE)

OMM(1)=CFOM(OPER1)+CFOM(OPER2)+CFOM(LABOR)

CFOM(POWER)=COST(POWER,OMMCF,KWH*HRSYR,IRCODE)

OMM(2)=CFOM(POWER)

CFOM(MECH1)=COST(MECH1,OMMCF,0.01*HRSYR,IRCODE)
CFOM(MECH2)=COST(MECH2,OMMCF,.009*HRSYR,IRCODE)
CFOM(HELPR)=COST(HELPR,OMMCF,.002*HRSYR,IRCODE)

OMM(3)=CFOM(MECH1)+CFOM(MECH2)+CFOM(HELPR)+0.005*CM(3)

OMM(4)=0; Not applicable

OMM(8)=0 Not applicable
```

Module Specific Parameters, Parameter Definitions

QINF	Influent flow rate (GPM)
VEXC	Volume of excavation (CY)

VCON	Volume of concrete (CY)
WSTR	Weight of support steel (lbs)
WLAPL	Weight of ladders and platforms (lbs)
KWH	Kilowatts/hour
SEPVAP	Percent of total discharge flow (GPM) represented by the condensate (expressed as a %)
QSTM	Steam demand (lbs/hr)
SLUDG	Sludge (concentrate) wasting rate

DECANTER

System Variables

```
IF(SL.GT.0.), GO TO 1
IF(OILSG.GT.0.),SL=OILSG
IF(VISCON.LE.0.),GO TO 2
IF(SH.LE.0.),GO TO 2
IF(SL.LE.0.),GO TO 2
DETENT=6.0*VISCON/(SH-SL)
IF(DETENT.LE.0.),DETENT=20.

VOL=DETENT*QINF*0.134
LEN=1.084*VOL**0.333
LANDAM=0.922*VOL**0.667
LANDAR=(SQRT(LANDAM)+6.0)**2.0
HRSYR=HRS*DAYS
WTNK=150.*QINF**0.736
PIPDIA=10.**(ALOGID(QINF)*0.4)
MECHA=4.71E-6*QINF**0.831
MECHB=3.76E-6*QINF**0.831
HELP=9.42E-7+QINF**0.831

QSIDE=QINF*OIL*1.0E-4
QINF=QINF-QSIDE
```

Performance

```
CFCM(CLRI )=COST(CLRI ,CAPCF,LANDAR,IRCODE)
CFCM(GRADE)=COST(GRADE,CAPCF,LANDAR,IRCODE)

CM(1)=CFCM(CLRI )+CFCM(GRADE)
```

```
CFCM(SLAB2)=COST(SLAB2,CAPCF,LANDAR/27,IRCODE)

CM(2)=CFCM(SLAB2)

CFCM(CSPLT)=COST(CSPLT,CAPCF,WTNK,IRCODE)
CFCM(PIPE6)=COST(PIPE6,CAPCF,PIPDIA*3*LEN,IRCODE)

CM(3)=CFCM(CSPLT)+CFCM(PIPE6)

CM(4)=0: Not applicable

CFCM(LAND)=COST(LAND,CAPCF,LANDAR,IRCODE)

CM(5)=CFCM(LAND)

CM(6)=0; Not applicable

CFOM(OPER1)=COST(OPER1,OMMCF,MSTAFF*HRSYR*0.001,IRCODE)
CFOM(OPER2)=COST(OPER2,OMMCF,MSTAFF*HRSYR*0.001,IRCODE)
CFOM(LABOR)=COST(LABOR,OMMCF,MSTAFF*HRSYR*0.018,IRCODE)

OMM(1)=CFOM(OPER1)+CFOM(OPER2)+CFOM(LABOR)

OMM(2)=0: Not applicable

CFOM(MECH1)=COST(MECH1,OMMCF,MECHA*HRSYR,IRCODE)
CFOM(MECH2)=COST(MECH2,OMMCF,MECHB*HRSYR,IRCODE)
CFOM(HELPR)=COST(HELPR,OMMCF,HELPR*HRSYR,IRCODE)

OMM(3)=CFOM(MECH1)+CFOM(MECH2)+CFOM(HELPR)

OMM(4)=0; Not applicable

OMM(8)=0; Not applicable
```

Module Specific Parameters, Parameter Definitions

VISCON	Viscosity of the continuous phase (centipoise)
SH	Specific gravity of the heavy phase
SL	Specific gravity of the light phase
DETENT	Detention time in unit
QINF	Influent flow (liquid)(GPM)
VOL	Volume of unit (ft^3)
LEN	Length (ft)

WTNK	Weight of the decanter tank (lbs)
PIPDIA	Diameter of piping (inches)
MECHA	Coefficient for MECH 1
MECHB	Coefficient for MECH 2
HELP	Coefficient for HELPR

Module Specific Parameters, Parameter Definitions

OILSG	Specific gravity of oil (lighter phase)
OIL	Concentration of oil (lighter phase (ppm)
QSIDE	Wasting rate of the lighter fraction to an accumulator (GPM)

CHEMICAL STORAGE: GAS

System Variables

```
DUR=30./DELMO
VOL=DUR*QGAS*60.*HRS
IFF(VOL.LT.2000.)
  LANDAR=VOL*0.02
  CYCLNO=RNDUP(VOL/150.)
  BOT=1.
  CYL=0.
ENDIFF
IFF(VOL.GE.2000.)
  LANDAR=VOL*0.04
  CYLNO=RNDUP(VOL/2000.)
  BOT=0.
  CYL=1.
ENDIFF
HRSYR=HRS*DAYS
```

Performance

```
CFCM(CLR1 )=COST(CLR1 ,CAPCF,LANDAR,IRCODE)
CFCM(GRADE)=COST(GRADE,CAPCF,LANDAR,IRCODE)

CM(1)=CFCM(CLR1 )+CFCM(GRADE)

CFCM(SLAB2)=COST(SLAB2,CAPCF,LANDAR/27,IRCODE)
CFCM(BUILD)=COST(BUILD,CAPCF,LANDAR,IRCODE)
```

```
CM(2)=CFCM(SLAB2)+CFCM(BUILD)

CFCM(VAPOR)=COST(VAPOR,CAPCF,1,IRCODE)
CFCM(CSAST)=COST(CSAST,CAPCF,CYLNO,IRCODE)

CM(3)=CFCM(VAPOR)+CFCM(CSAST)

CM(4)=0; Not applicable

CFCM(LAND)=COST(LAND,CAPCF,LANDAR,IRCODE)

CM(5)=CFCM(LAND)
CM(6)=0; Not applicable

CFOM(OPER1)=COST(OPER1,OMMCF,MSTAFF*HRSYR*0.001,IRCODE)
CFOM(OPER2)=COST(OPER2,OMMCF,MSTAFF*HRSYR*0.001,IRCODE)
CFOM(LABOR)=COST(LABOR,OMMCF,MSTAFF*HRSYR*0.009,IRCODE)

OMM(1)=CFOM(OPER1)+CFOM(OPER2)+CFOM(LABOR)

OMM(2)=0; Not applicable

OMM(3)=0.01*CM(3)

CFOM(CLBOT)=COST(CLBOT,OMMCF,VOL*BOT*DAYS/DUR,IRCODE)
CFOM(CLCYL)=COST(CLCYL,OMMCF,VOL*CYL*DAYS/DUR,IRCODE)

OMM(4)=CFOM(CLBOT)+CFOM(CLCYL)

OMM(8)=0; Not applicable
```

Module Specific Parameters, Parameter Definitions

DELMO	Deliveries per month
DUR	Duration between deliveries (days)
VOL	Volume of delivery (and of storage capacity)
CYLNO	Number of containers
BOT	Equals 1 if bottles are used
CYL	Equals 1 if cylinders are used
QGAS	Gas output (demand) (lbs/min)

CHEMICAL STORAGE: LIQUID

System Variables

```
DUR=30/DELMO
VOL=DUR*QLIQ*60*HRS
LANDAM=VOL/10
LANDAR=LANDAM+12*SQRT(LANDAM)+144
VEXC=LANDAM/13.5
VRING=LANDAM/16.2
MECHA=9.79E-3*QLIQ**0.831
MECHB=7.83E-3*QLIQ**0.831
HELP=1.96E-3*QLIQ**0.831
IBTNK=1
WA=AL=FE=CA=FUELO=GASO=AM=PH=DM=0
IF(MODL.EG.1),WA=1
IF(MODL.EQ.2),AL=1
IF(MODL.EQ.3),FE=1
IF(MODL.EQ.4),CA=1
IF(MODL.EQ.5),FUELO=1
IF(MODL.EQ.6),GASO=1
IF(MODL.EQ.7),AM=1
IF(MODL.EQ.8),PH=1
IF(MODE.EQ.9)DM=1
IF(WA.EQ.1),TANK=1
IF(WA.EQ.1),FIBTNK=0
IF(WA.EQ.1),AMTNK=0
IF(AM.EQ.1),TANK=0
IF(AM.EQ.1),FIBTNK=0
IF(AM.EQ.1),AMTNK=1
IF(AM.EQ.1),TANK=0
IF(AM.EQ.1),FIBTNK=0
IF(AM.EQ.1),AMTNK=1
HRSYR=DAYS*HRS
CONSUM=VOL*DAYS/DUR
IF(MODL.EQ.0),TANK=1
IF(MODL.EQ.0),FIBTNK=0
```

Performance

```
CFCM(CLR2 )=COST(CLR2 ,CAPCF,LANDAR,IRCODE)
CFCM(GRADE)=COST(GRADE,CAPCF,LANDAM,IRCODE)
CFCM(EXCV1)=COST(EXCV1,CAPCF,VEXC,IRCODE)

CM(1)=CFCM(CLR2 )+CFCM(GRADE)+CFCM(EXCV1)

CFCM(WALL1)=COST(WALL1,CAPCF,VRING,IRCODE)

CM(2)=CFCM(WALL1)
```

```
CFCM(SSTSH)=COST(SSTSH,CAPCF,VOL*TANK,IRCODE)
CFCM(PRTNK)=COST(PRTNK,CAPCF,VOL*AMTNK,IRCODE)
CFCM(FTANK)=COST(FTANK,CAPCF,VOL*FIBTNK,IRCODE)

CM(3)=CFCM(SSTSH)+CFCM(PRTNK)+CFCM(FTANK)

CM(4)=0; Not applicable

CFCM(LAND)=COST(LAND,CAPCF,LANDAR,IRCODE)

CM(5)=CFCM(LAND)

CM(6)=0; Not applicable

CFOM(OPER1)=COST(OPER1,OMMCF,MSTAFF*HRSYR*0.001,IRCODE)
CFOM(OPER2)=COST(OPER2,OMMCF,MSTAFF*HRSYR*0.001,IRCODE)
CFOM(LABOR)=COST(LABOR,OMMCF,MSTAFF*HRSYR*0.018,IRCODE)

OMM(1)=CFOM(OPER1)+CFOM(OPER2)+CFOM(LABOR)

OMM(2)=0; Not applicable

CFOM(MECH1)=COST(MECH1,OMMCF,MECHA*HRSYR,IRCODE)
CFOM(MECH2)=COST(MECH2,OMMCF,MECHB*HRSYR,IRCODE)
CFOM(HELPR)=COST(HELPR,OMMCF,HELP*HRSYR,IRCODE)

OMM(3)=CFOM(MECH1)+CFOM(MECH2)+CFOM(HELPR)

CFOM(WATER)=COST(WATER,OMMCF,WA*CONSUM,IRCODE)
CFOM(ALSU3)=COST(ALSU3,OMMCF,AL*CONSUM,IRCODE)
CFOM(FECL3)=COST(FECL3,OMMCF,FE*CONSUM,IRCODE)
CFOM(COACL)=COST(COACL,OMMCF,CA*CONSUM,IRCODE)
CFOM(FUEL)=COST(FUEL  ,OMMCF,FUELO*CONSUM,IRCODE)
CFOM(GAS )=COST(GAS   ,OMMCF,GASO*CONSUM,IRCODE)
CFOM(AMMON)=COST(AMMON,OMMCF,AM*CONSUM,IRCODE)
CFOM(PHOS)=COST(PHOS  ,OMMCF,PH*CONSUM,IRCODE)
CFOM(DEMUL)=COST(DEMUL,OMMCF,DM*CONSUM,IRCODE)
OMM(4)+CFOM(WATER)+CFOM(ALSU3)+CFOM(FECL3)+CFOM(COACL)+CFOM(FUEL)+
CFOM(GAS)+CFOM(AMMON)+CFOM(PHOS)+CFOM(DEMUL)

OMM(8)=0; Not applicable
```

CHEMICAL STORAGE: SOLIDS

System Variables

```
AL=CAO=CAHY=DOLY=0
IF(MODS.EQ.1) AL=1  ,CONC=14.29,DENS=2.71
IF(MODS.EQ.2)CAO=1  ,CONC= 1.05,DENS=3.30
IF(MODS.EQ.3)CAHY=1,CONC= 1.37,DENS=2.24
IF(MODS.EQ.4)POLY=1,CONC= 1.0 ,DENS=2.00
```

```
IF(PERCENT.LE.0)PERCENT=20
AEFBIN=AEFSLA*5.0*PERCENT
DUR=(30/DELMO)*0.66*HRS
VOLBIN=DUR*QEFBIN*CONC*(1/DENS)*0.12
VOLSLA=QEFSLA*1.0
LANDAM=((VOLBIN+VOLSLA)*0.134)**0.667
LANDAR=1.5XLANDAR
VCON=LANDAM/27
WSTR=17.5*LANDAM+5.75*SQRT(LANDAM)+17.1
PIPLEN=SQRI(QEFSLA)
HRSYR=HRS*DAYS
MECHA=6.0E-4*QEFSLA**0.831
MECHB=5.0E-4*QEFSLA**0.831
HELP =1.0E-4*QEFSLA**0.831
```

Performance

```
CFCM(CLRl )=COST(CLRl ,CAPCF,LANDAR,IRCODE)
CFCM(GRADE)=COST(GRADE,CAPCF,LANDAM,IRCODE)

CM(1)=CFCM(CLRl )+CFCM(GRADE)

CFCM(SLAB2)=COST(SLAB2,CAPCF,VCON,IRCODE)
CFCM(STRST)=COST(STRST,CAPCF,WSTR,IRCODE)

CM(2)=CFCM(SLAB2)+CFCM(STRST)

CFCM(PIPE5)=COST(PIPE5,CAPCF,PIPLEN,IRCODE)
CFCM(SSTSH)=COST(SSTSH,CAPCF,VOLBIN,IRCODE)
CFCM(SLAKEO+COST(SLAKE,CAPCF,QEFBIN,IRCODE)
CFCM(VIBFD)=COST(VIBFD,CAPCF,QEFBIN/2000,IRCODE)
CM(3)=CFCM(PIPES)+CFCM(SSTSH)+CFCM(SLAKE)+CFCM(VIBFD)

CM(4)=0; Not applicable

CFCM(LAND)=COST(LAND,CAPCF,LANDAR,IRCODE)

CM(5)=CFCM(LAND)

CM(6)=0; Not applicable

CFOM(OPERl)=COST(OPERl,OMMCF,MSTAFF*HRSYR*0.001,IRCODE)
CFOM(OPER2)=COST(OPER2,OMMCF,MSTAFF*HRSYR*0.001,IRCODE)
CFOM(LABOR)=COST(LABOR,OMMCF,MSTAFF*HRSYR*0.018,IRCODE)

OMM(l)=CFOM(OPERl)+CFOM(OPER2)+CFOM(LABOR)

OMM(2)=0; Not applicable
```

```
CFOM(MECH1)=COST(MECH1,OMMCF,MECHA*HRSYR,IRCODE)
CFOM(MECH2)=COST(MECH2,OMMCF,MECHB*HRSYR,IRCODE)
CFOM(HELPR)=COST(HELPR,OMMCF,HELP*HRSYR,IRCODE)

OMM(3)=CFOM(MECH1)+CFOM(MECH2)+CFOM(HELPR)

CFOM(ALSU2)=COST(ALSU2,OMMCF,QEFBIN*AL*HRSYR,IRCODE)
CFOM(CAO1 )=COST(CAO1 ,OMMCF,QEFBIN*CAO*HRSYR,IRCODE)
CFOM(CAHY1)=COST(CAHY1,OMMCF,QEFBIN*CAHY*HRSYR,IRCODE)
CFOM(POLYM)=COST(POLYM,OMMCF,QEFBIN*POLY*HRSYR,IRCODE)

OMM(4)=CFOM(ALSU2)+CFOM(CAO1 )+CFOM(CAHY1)+CFOM(POLYM)

OMM(8)=0; Not applicable
```

SLUDGE EQUALIZATION

System Variables

```
NOTNKS=RNDUM(IMPT 155.)
LENGTH=AMAX1(8.0,(INPT/NOTNKS)*.0447)
LANDAR=LENGTH*12.
HRSYR=HRS*DAYS
KWH=37.29*NOTNKS
```

Performance

```
CFCM(CLR1 )=COST(CLR1 ,CAPCF,LANDAR,IRCODE)
CFCM(GRADE)=COST(GRADE,CAPCF,LANDAR,IRCODE)

CM(1)=(CFCM(CLR1 )+CFCM(GRADE))*NOTNKS

CFCM(SLAB1)=COST(SLAB1,CAPCF,LENGTH*0.3,IRCODE)
CFCM(WALL5)=COST(WALL5,CAPCF,2.8+0.35*LENGTH,IRCODE)
CFCM(COVER)=COST(COVER,CAPCF,300,IRCODE)

CM(2)=CFCM(SLAB1)=CFCM(WALL5)+CFCM(COVER)*1000)*NOTNKS

CFCM(AER50)=COST(AER50,CAPCF,NOTNKS,IRCODE)

CM(3)=CFCM(AER50)

CM(4)=0; Not applicable

CFCM(LAND)=COST(LAND,CAPCF,LANDAR*NOTNKS,IRCODE)

CM(5)=CFCM(LAND)
```

```
CM(6)=0; Not applicable

CFOM(OPER1)=COST(OPER1,OMMCF,MSTAFF*HRSYR*0.125,IRCODE)
CFOM(OPER2)=COST(OPER2,OMMCF,MSTAFF*HRSYR*0.007,IRCODE)
CFOM(LABOR)=COST(LABOR,OMMCF,MSTAFF*HRSYR*0.900,IRCODE)

OMM(1)=CFOM(OPER1)+CFOM(OPER2)+CFOM(LABOR)

CFOM(POWER)=COST(POWER,OMMCF,KWH*HRSYR,IRCODE)

OMM(2)=CFOM(POWER)

CFOM(SUPER)=COST(SUPER,OMMCF,16,IRCODE)
CFOM(MECH1)=COST(MECH,OMMCF,32,IRCODE)
CFOM(HELPR)=COST(HELPR,OMMCF,40,IRCODE)

OMM(3)=CFOM(SUPER)+CFOM(MECH1)+CFOM(HELPR)

OMM(4)=0; Not applicable

OMM(8)=0; Not applicable
```

Module Specific Parameters, Parameters Definitions

SLUDG	Input/output flow for sludge (GPM)
NOTNKS	Number of tanks
LENGTH	Basin length (ft)
KWH	Kilowatts/hr
INDT	Sludge flow input (GPM)

ENCAPSULATION

System Variables

```
HRSYR=HRS*DAYS
TONSYR=QINFS*HRSYR/2000.
LNADAR=25.0*TONSYR
WORKER=1.60E-3*TONSYR
KWH=2.06E-2*TONSYR
CHEM=0.647*TONSYR
IFF(MODE.EQ.1.)
 MODE1=1.
 MODE2=0.
ENDIFF
```

```
      IFF(MODE.EQ.2.)
       MODE1=0.
       MODE2=1.
      ENDIFF

      QINFS=1.647*QINES
```

Performance

```
      CFCM(CLR1 )=COST(CLR1 ,CAPCF,LANDAR,IRCODE)
      CFCM(GRADE)=COST(GRADE,CAPCF,LANDAR,IRCODE)

      CM(1)=(CFCM(CLR1 )+CFCM(GRADE))*MODE1

      CFCM(SLAB2)=COST(SLAB2,CAPCF,LANDAR/27,IRCODE)
      CFCM(BUILD)=COST(BUILD,CAPCF,LANDAR,IRCODE)

      CM(2)=(CFCM(SLAB2)+CFCM(BUILD))*MODE1

      CFCM(ENCAP)=COST(ENCAP,CAPCF,TONSYR,IRCODE)

      CM(3)=CFCM(ENCAP)*MODE1

      CM(4)=0.05*CM(3)

      CFCM(LAND)=COST(LAND,CAPCF,LANDAR,IRCODE)

      CM(5)=CFCM(LAND)*MODE1

      CM(6)=0; Not applicable

      CFOM(OPER1)=COST(OPER1,OMMCF,WORKER*HRSYR,IRCODE)

      OMM(1)=CFOM(OPER1)*MODE1

      CFOM(POWER)=COST(POWER,OMMCF,KWH*HRSYR,IRCODE)

      OMM(2)=CFOM(POWER)*MODE1

      OMM(3)=0.01*CM(3)*MODE1

      CFOM(CAPCM)=COST(CAPCM,OMMCF,CHEM,IRCODE)

      OMM(4)=CFOM(CAPCFM)*MODE1

      CFOM(ENCAP)=COST(ENCAP,OMMCF,TONSYR,IRCODE)

      OMM(8)=CFOM(ENCAP)*MODE2
```

Module Specific Parameters, Parameter Definitions

QINFS	Solids loading rate (lbs/hr)
TONSYR	Tons per year input
WORKER	Coefficient for OPER1
KWH	Kilowatts/hr
CHEM	Chemical demands (tons)
MODE	Mode=1 →purchased plant Mode=2 →service fee

DEAERATOR

System Variables

```
NODEA=RNDUP(QINF/80.)
INFLOW=QINF/NODEA
LANDAM=(99.85+18.89*INFLOW)**0.54*NODEA
LANDAR=(SQRT(LANDAM)+6)**2
HRSYR=HRS*DAYS

OXY=0.01*OXY
QSTM=1.1347+0.11184*INFLOW)**1.25*NODEA/1000.

CFCM(CLR1 )=COST(CLR1 ,CAPCF,LANDAR,IRCODE)
CFCM(GRADE)=COST(GRADE,CAPCF,LANDAR,IRCODE)

CM(1)=CFCM(CLR1 )+CFCM(GRADE)

CFCM(SLAB2)=COST(SLAB2,CAPCF,LANDAR/27,IRCODE)
CFCM(BUILD)=COST(BUILD,CAPCF,LANDAM,IRCODE)

CM(2)=CFCM(SLAB2)+CFCM(BUILD)

CFCM(DEARA)=COST(DEARA,CAPCF,INFLOW,IRCODE)

CM(3)=CFCM(DEARA)*NODEA

CM(4)=0; Not applicable

CFCM(LAND)=COST(LAND,CAPCF,LANDAR,IRCODE)

CM(5)=CFCM(LAND)

CM(6)=0; Not applicable
```

```
CFOM(OPER1)=COST(OPER1,OMMCF,MSTAFF*HRSYR*0.001,IRCODE)
CFOM(OPER2)=COST(OPER2,OMMCF,MSTAFF*HRSYR*0.001,IRCODE)
CFOM(LABOR)=COST(LABOR,OMMCF,MSTAFF*HRSYR*0.018,IRCODE)

OMM(1)=CFOM(OPER1)+CFOM(OPER2)+CFOM(LABOR)

OMM(2)=0; Not applicable

OMM(3)=0.01*CM(3)
OMM(4)=0; Not applicable

OMM(8)=0; Not applicable
```

Module Specific Parameters, Parameters Definitions

QINF	Influent liquid flow (GPM)
NODEA	Number of deaerators required
INFLOW	Flow rate to a single aerator(GPM)
OXY	oxygen concentration (ppm)
QSTM	Steam demand lbs/hr

EVAPORATION POND

System Variables

```
VOLW=BATLH*QINF*60.*HRS
SURFAR=1.6*VOLN/(EVAP-RAIN)
LANDAR=(SQRT(SURFAR)+92)**@.
VEXC=(RAIN/12+VOLW/(&.$**SURFAR))*SURFAR
HRSYR=DAYS*HRS

QINF=0
```

Performance

```
CFCM(CLR2 )=COST(CLR2 ,CAPCF,LANDAR,IRCODE)
CFCM(GRADE)=COST(GRADE,CAPCF,LANDAR,IRCODE)
CFCM(EXCV3)=COST(EXCV3,CAPCF,VEXC,IRCODE)

CM(1)=CFCM(CLR2 )+CFCM(GRADE)+CFCM(EXCV3)

CM(2)=0; Not applicable
```

```
CM(3)=0; Not applicable

CM(4)=0; Not applicable

CFCM(LAND)=COST(LAND,CAPCF,LANDAR,IRCODE)

CM(5)=CFCM(LAND)

CFCM(LINER)=COST(LINER,CAPCF,1.05*LANDAR,IRCODE)
CFCM(GWMON)=COST(GWMON,CAPCF,4,IRCODE)

CM(6)=CFCM(LINER)+CFCM(GWMON)

CFOM(OPER1)=COST(OPER1,OMMCF,MSTAFF*HRSYR*0.125,IRCODE)
CFOM(OPER2)=COST(OPER2,OMMCF,MSTAFF*HRSYR*0.065,IRCODE)
CFOM(LABOR)=COST(LABOR,OMMCF,MSTAFF*HRSYR*0.342,IRCIDE)

OMM(1)=CFOM(OPER1)+CFOM(OPER2)+CFOM(LABOR)

OMM(2)=0; Not applicable
CFOM(LABOR)=COST(LABOR,OMMCF,30,IRCODE)

OMM(3)=CFOM(LABOR)

OMM(4)=0; Not applicable

OMM(8)=0; Not applicable
```

Module Specific Parameters, Parameters Definitions

QINF	Influent flow (liquid) (GPM)
VOLW	Volume of water to be retained (gal)
EVAP	Evaporation rate (inches per year)
RAIN	Rainfall (inches per year)
BATCH	Duration of retention of a batch (days)
VEXC	Volume of excavation (CY)

STEAM GENERATOR

System Variables

```
NOBOIL=RNDUP)QSTM/17250.)
OUTPUT=QSTM/NOBOIL
```

```
LANDAM=4.33E-3*QSTM
  OIL=8.61E-3*QSTM
  GAS=1.103*QSTM
  HZO=0.1719*QSTM
  HP=2.833E-3*QSTM
  KWH=HP*0.7457
  HRSYR=HRS*DAYS
  LANDAR=LANDAM+12.*SQRT(LANDAM)+144.
IFF(MODE.EQ.1.)
  NAT=0.
  F=1.
ENDIFF
IFF(MODE.EQ.2.)
  NAT=1.
  F=0.
ENDIFF


TOTAL OUTPUT(LBS/HR)AS QSTM
```

Performance

```
CFCM(CLR1 )=COST(CLR1 ,CAPCF,LANDAR,IRCODE)
CFCM(GRADE)=COST(GRADE,CAPCF,LANDAR,IRCODE)

CM(1)=CFCM(CLR1 )+CFCM(GRADE)

CFCM(SLAB2)=COST(SLAB2,CAPCF,LANDAR/27,IRCODE)
CFCM(BUILD)=COST(BUILD,CAPCF,LANDAR,IRCODE)

CM(2)=CFCM(SLAB2)+CFCM(BUILD)

CFCM(STGEN)=COST(STGEN,CAPCF,OUTPUT,IRCODE)

CM(3)=CFCM(STGEN)*NOBOIL

CM(4)=0; Not applicable

CFCM(LAND)=COST(LAND,CAPCF,LANDAR,IRCODE)

CM(5)=CFCM(LAND)

CM(6)=0; Not applicable

CFOM(OPER1)=COST(OPER1,OMMCF,MSTAFF*HRSYR*0.020,IRCODE)
CFOM(OPER2)=COST(OPER2,OMMCF,MSTAFF*HRSYR*0.003,IRCODE)
CFOM(LABOR)=COST(LABOR,OMMCF,MSTAFF*HRSYR*0.304,IRCODE)

OMM(1)=CFOM(OPER1)+CFOM(OPER2)_CFOM(LABOR)
```

```
CFOM(FUEL)=COST(FUEL ,OMMCF,F*OIL*HRSYR,IRCODE)
CFOM(NGAS)+COST(NGAS ,OMMCF,NAT*GAS*HRSYR,IRCODE)
CFOM(POWER)=COST(POWER,OMMCF,KWH*HRSYR,IRCODE)

OMM(2)=CFOM(FUEL)+CFOM(NGAS)+CFOM(POWER)

CFOM(MECH1)=COST(MECH1,OMMCF,32,IRCODE)
CFOM(MECH2)=COST(MECH2,OMMCF,16,IRCODE)
CFOM(HELPR)=COST(HELPR,OMMCF,32,IRCODE)

OMM(3)=CFOM(MECH1)+CFOM(MECH2)+CFOM(HELPR)+0.005*CM(3)

CFOM(WATER)=COST(WATER,OMMCF,HZO*HRSYR,IRCODE)

OMM(4)=CFOM(WATER)

OMM(8)=0: Not applicable
```

Module Specific Parameters, Parameters Definitions

QSTM	Steam demand (lbs/hr)
NOBOIL	Number of boilers required
OUTPUT	Steam required from one boiler (lbs/hr)
OIL	Gallons of fuel oil required (gal)
GAS	Natural gas required (ft^3)
H2O	Gallons of water required (gal)
HP	Horsepower required
KWH	Kilowatts/hr

Module Specific Parameters, Parameters Definitions

MODE	If MODE = 1, then boilers are oil fired If MODE = 2, then boilers are fired by natural gas
NAT) F)	Counters controlled by MODE

BUILDING

System Variables

```
+CLR1  = 80
+GRADE = 82
+OFFIC = 72
+RLABS = 73
+LAND  = 50

+HELPR = 12

IQINFL = 01
IQINFS = 02

SCALE=QINFL
IF(SCALE.LE.0)SCALE=QINFS*2.0E-3
LANDAM=150.*(1.81E-3*SCALE+5.48)+500.
LANDAR=2.*LANDAM
```

Performance

```
CFCM(CLR1 )=COST(CLR1 ,CAPCF,LANDAR,IRCODE)
CFCM(GRADE)=COST(GRADE,CAPCF,LANDAM,IRCODE)

CM(1)=CFCM(CLR1 )+CFCM(GRADE)

CM(2)=0; Included in CM-3

CFCM(OFFICE)=COST(OFFICE,CAPCF,LANDAM,IRCODE)
CFCM(RLABS)=COST(RLABS,CAPCF,500 ,IRCODE)

CM93)=CFCM(OFFICE)+CFCM(RLABS)

CM(4)=0; Included in CM-3

CFCM(LAND)=COST(LAND,CAPCF,LANDAR,IRCODE)

CM(5)=CFCM(LAND)

CM(6)=0; Not applicable

OMM(1)=0; Not applicable

OMM(2)=0; Not applicable


CFOM(HELPR)=COST(HELPR,OMMCF,52,IRCODE)
```

```
OMM(3)=CFOM(HELPR)

OMM(4)=0; Not applicable

OMM(8)=0; Not applicable
```

Module Specific Parameters, Parameters Definitions

QINFL	Liquid flow rate input to the associated technology (GPM)
QINFS	Solids loading rate to the associated technology (lbs/hr)
SCALE	Relates QINFS or QINFL to sizing variables

PIPING AND VALUES

System Variables

```
IF(LENGTH.LE.0),LENGTH=QINF
  LANDAR=LENGTH*3.0
  DIA=12.*(3.14E-11*LENGTH*QINF*QINF)**0.2
```

Performance

```
CFCM(CLR1 )=COST(CLR1 ,CAPCF,LANDAR,IRCODE)
CFCM(GRADE)=COST(GRADE,CAPCF,LANDAR,IRCODE)

CM(1)=CFCM(CLR1 )+CFCM(GRADE)

CM(2)=0; Not applicable

CFCM(PIPE6)=COST(PIPE6,CAPCF,DIA,IRCODE)*LENGTH

CM(3)=CFCM(PIPE6)

CM(4)=0; Not applicable

CFCM(LAND)=COST(LAND,CAPCF,LANDAR,IRCODE)

CM(5)=CFCM(LAND)

CM(6)=0; Not applicable
```

```
CFOM(OPER1)=COST(OPER1,OMMCF,MSTAFF*HRSYR*0.000,IRCODE)
CFOM(OPER2)=COST(OPER2,OMMCF,MSTAFF*HRSYR*0.000,IRCODE)
CFOM(LABOR)=COST(LABOR,OMMCF,MSTAFF*HRSYR*0.010,IRCODE_

OMM(1)=CFOM(OPER1)+CFOM(OPER2)+CFOM(LABOR)

OMM(2)=0; Not applicable

OMM(3)=0.005*CM(3)

OMM(4)=0; Not applicable

OMM(8)=0; Not applicable
```

Module Specific Parameters, Parameters Definitions

QINF	Liquid flow input to technology (GPM)
LENGTH	Length of piping in (ft)-optional
DIA	Pipe and valve diameter

PUMP

System Variables

```
IFF(MODE.EQ.1.)
NOPUMPS=RNDUP(GINF/2000.)
AQ=1.
SL=0.
CM=0.
ENDIFF
IFF(MODE.EQ.2.)
NOPUMPS=RNDUP(SLUDG/2000.)
AQ=0
SL=1.
CM=0.
ENDIFF
IFF(MODE.EQ.5.)
NOPUMPS=RNDUP(QCHEM/2000.)
AQ=0.
SL=0.
CM=1.
ENDIFF
FLOWPP=QINF/NOPUMPS
KWH=NOPUMPS*FLOWPP*2.371E-2
HRSYR=HRS*DAYS
```

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Performance

```
CM(1)=0; Not applicable

CM(2)=0; Not applicable

CFCM(PUMP3)=COST(PUMP3,CAPCF,FLOWPP*AQ,IRCODE)
CFCM(PUMP2)=COST(PUMP2,CAPCF,FLOWPP*SL,IRCODE)
CFCM(PUMP1)=COST(PUMP1,CAPCF,FLOWPP*CM,IRCODE)

CM(3)=CFCM(PUMP3)+CFCM(PUMP2)+CFCM(PUMP1)*NOPUMPS

CM(4)=0.005*CM(3)

CFCM(LAND)=COST(LAND,CAPCF,LANDAR,IRCODE)
CM(5)=0; Not applicable

CM(6)=0; Not applicable

CFOM(OPER1)=COST(OPER1,OMMCF,MSTAFF*HRSYR*0.001,IRCODE)
CFOM(OPER2)=COST(OPER2,OMMCF,MSTAFF*HRSYR*0.001,IRCODE)
CFOM(LABOR)=COST(LABOR,OMMCF,MSTAFF*HRSYR*0.051,IRCODE)

OMM(1)=CFOM(OPER1)+CFOM(OPER2)+CFOM(LABOR)

CFOM(POWER)=COST(POWER,OMMCF,KWH*HRSYR,IRCODE)

OMM(2)=CFOM(POWER)

OMM(3)=0.01*CM(3)

OMM(4)=0; Not applicable

OMM(8)=0; Not applicable
```

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